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# Evaluation of two soft manual toothbrushes with different filament designs in relation to gingival abrasion and plaque removing efficacy

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Versteeg PA, Rosema NAM, Timmerman MF, Van der Velden U, Van der Weijden GA. Evaluation of two soft manual toothbrushes with different filament designs in relation to gingival abrasion and plaque removing efficacy.



**Abstract:** *Objectives:* To evaluate the effect of two soft manual toothbrushes with different filament and brush head designs in relation to gingival abrasion and plaque removing efficacy to the in relation flat trimmed manual reference toothbrush of the American Dental Association (ADA). *Methods:* The study had a randomized single use cross-over model ($n = 76$) with three sessions whereby all brushes were used by each subject. Subjects were asked to abstain from all oral hygiene procedures for 48 h. They brushed according to split-mouth design. Pre- and post-brushing plaque and gingival abrasion were assessed. *Results:* The Sensodyne® Sensitive (SENS) was more abrasive than the ADA ($P < 0.001$) while the Oral-B® Sensitive Advantage® (OBSA) was less abrasive than the SENS ($P < 0.001$). There was no statistically significant difference between the OBSA and the ADA ($P = 0.319$). All three brushes showed statistically significant reductions (49–56%) in plaque versus baseline. Compared to the ADA and the SENS, the OBSA had a smaller percentage of plaque removal (56% versus 49%, $P \leq 0.001$; and 50% versus 52%, $P = 0.028$). *Conclusions:* The present study which compared two soft toothbrushes showed that the OBSA caused less gingival abrasion compared to the SENS-brush with a marginal loss (2%) of efficacy.

**Key words:** clinical trial; gingival abrasion; manual toothbrush; plaque

## Introduction

Effective plaque control is critical to the maintenance of oral health, because plaque is the primary etiological factor in the introduction and development of both caries and periodontal disease (1). Plaque removal with a manual toothbrush represents the most frequently used method of oral hygiene in Western Society. A toothbrush should be able to reach and clean effeciently most areas of the mouth. The choice is usually a matter of individual preference rather than a demonstrated superiority of any one type.

During the 18th century, the bristle toothbrush took its place. The most recent development in toothbrush manufactering technology has been in the individual toothbrush filaments. Now, in addition to the standard filament round shape, filaments are available in square, hexagonal and other shapes with varying surface textures ranging from smooth to rough. There are also variable lengths of toothbrush filaments and those with tapered and/or feathered filament ends (1). The degree of hardness and stiffness of the filaments is influenced by the filament material and its diameter and length. Toothbrushes with bigger filament diameters (>0.2 mm) are harder and less flexible. This increased stiffness results in the filament ends not bending back during brushing, with the potential of damaging the gums, thus destroying the protective keratin layer (2).

Opinions regarding the merits of hard and soft brisltes are based upon studies carried out under different conditions and are often inconclusive and not in agreement with each other. Soft filaments seems to clean better than hard filaments because of the 'matting effect' produced by the combination of soft filaments and dentifrice. This increases tooth-dentifrice contact and adds the cleasing action, but could also increase tooth abrasion (3). However, the filament must be sufficiently stiff so that during brushing enough pressure is exerted to remove the plaque. In this context the cleaning performance determines the lower limit for filament diameter as the manner in which a brush is used affects the cleansing action and abrasion (4).

Gum damage potential is also influenced by the degree of hardness and stiffness of the filaments. As early as 1729 the severe stiffness of brushes was condemded by observant dentists such as Fauchard, as having a destructive action on the gingiva (5). Since patients are reluctant to injure themselves, the marginal areas are avoided when the hard brushes are used. The Bass method (6) is widely accepted as an effective method for bacterial plaque removal adjacent to and directly beneath the gingival margin. It has been demonstrated to be more effective than other methods in cleaning the gingival zones of the teeth, regions of prime interest to the periodontist (7). This shows the need of soft nylon filament brushes. The soft nylon filament with rounded ends are less traumatic and can be directed into the gingival sulcus minimizing pain, lacerations or gingival or cervical abrasion. The advantages are obvious in that the lack of assiociated trauma enables the patients to direct the filaments into the areas of greatest concern (8).

The objective of the present study was to evaluate the effect of two soft manual toothbrushes with different filament and brush head designs in relation to gingival abrasion and plaque removing efficacy to the in relation flat trimmed manual reference toothbrush of the American Dental Association (ADA).

## Material and methods

### Subjects

For this study healthy subjects including both genders were recruited ($n$ = 76) from non-dental students of the Amsterdam Universities. To participate, subjects were required to fulfil the following inclusion criteria: a minimum of five evaluable teeth in each quadrant (with no partial dentures, orthodontic banding or wires); absence of oral lesions and or periodontal pockets >5 mm. 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 05/203).

### Toothbrushes

In this study three toothbrushes were used: (i) Oral-B® Sensitive Advantage® toothbrush (OBSA), (ii) Sensodyne® Sensitive (SENS) and (iii) a manual ADA flat trimmed reference toothbrush (ADA).

Oral-B Senstive Advantage had soft, end-rounded filaments configured with an angled profile on the toe, and a flat trim on the heel of the toothbrush (Fig. 1a). The brush has 41 tufts. Sensodyne Sensitive had soft, end-rounded filaments and a dome shaped head. The brush had 33 tufts (Fig. 2a). ADA flat trimmed reference toothbrush (CB) had soft end-rounded cylindrical filaments. The brush had 47 tufts (Fig. 3a).

### Study design

The study had a randomized single use cross-over model with three sessions whereby all brushes were used by

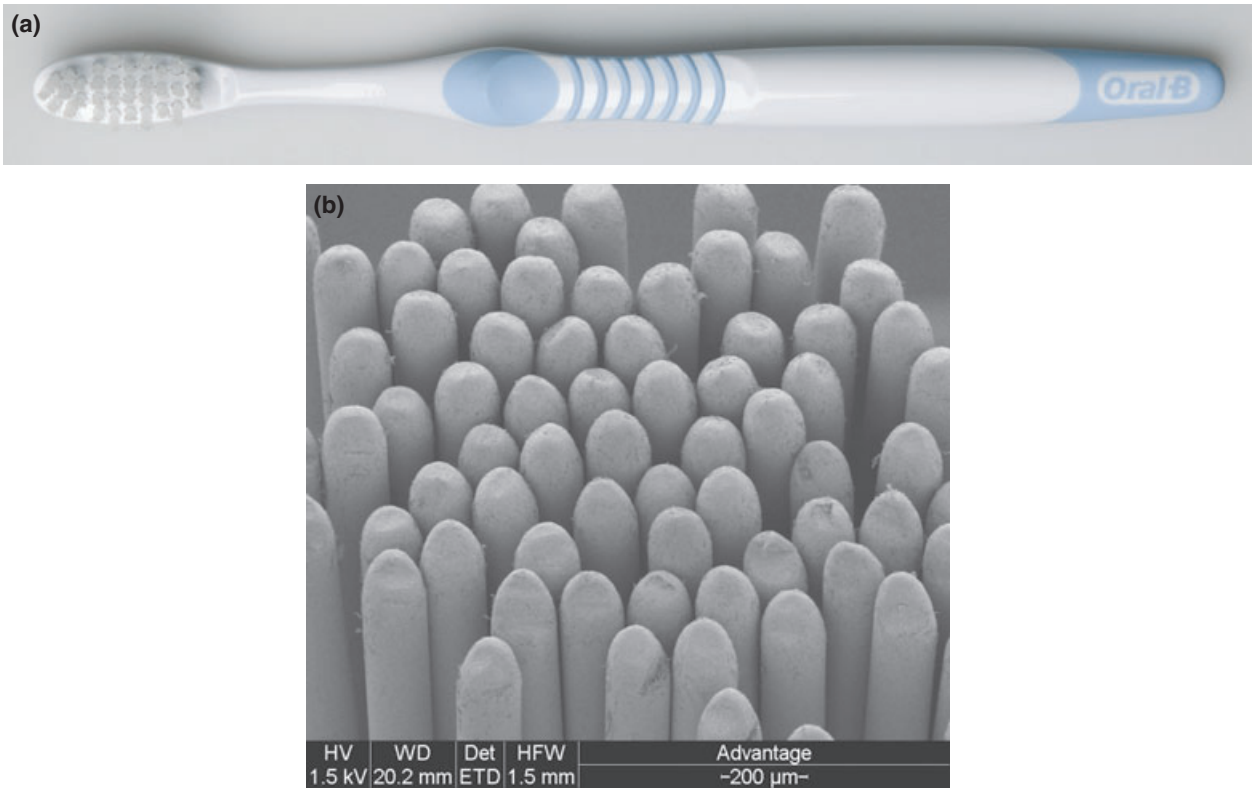


*Fig. 1.* (a) Oral-B Advantage Sensitive-brush; (b) at 100× magnification.

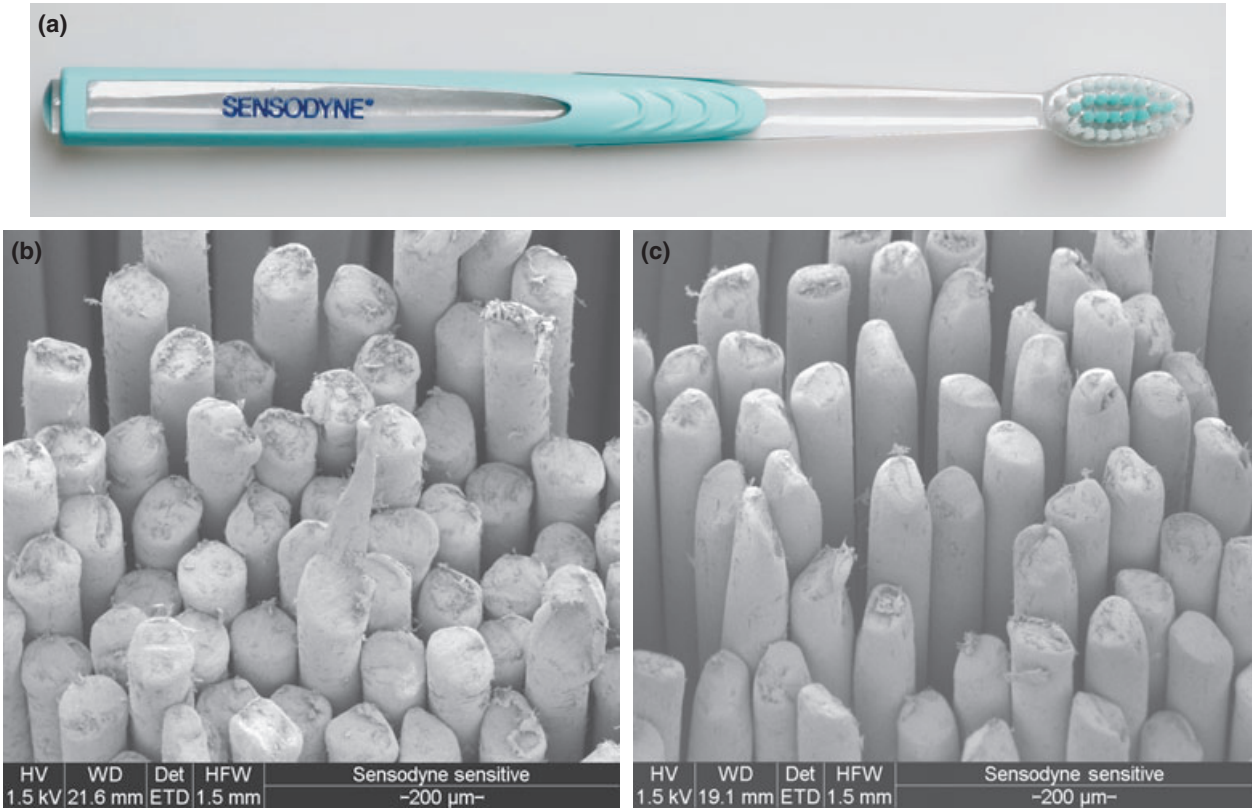


*Fig. 2.* (a) Sensodyne Sensitive-brush; (b) at 100× magnification (white outer filaments); (c) at 100× magnification (blue inner filaments).

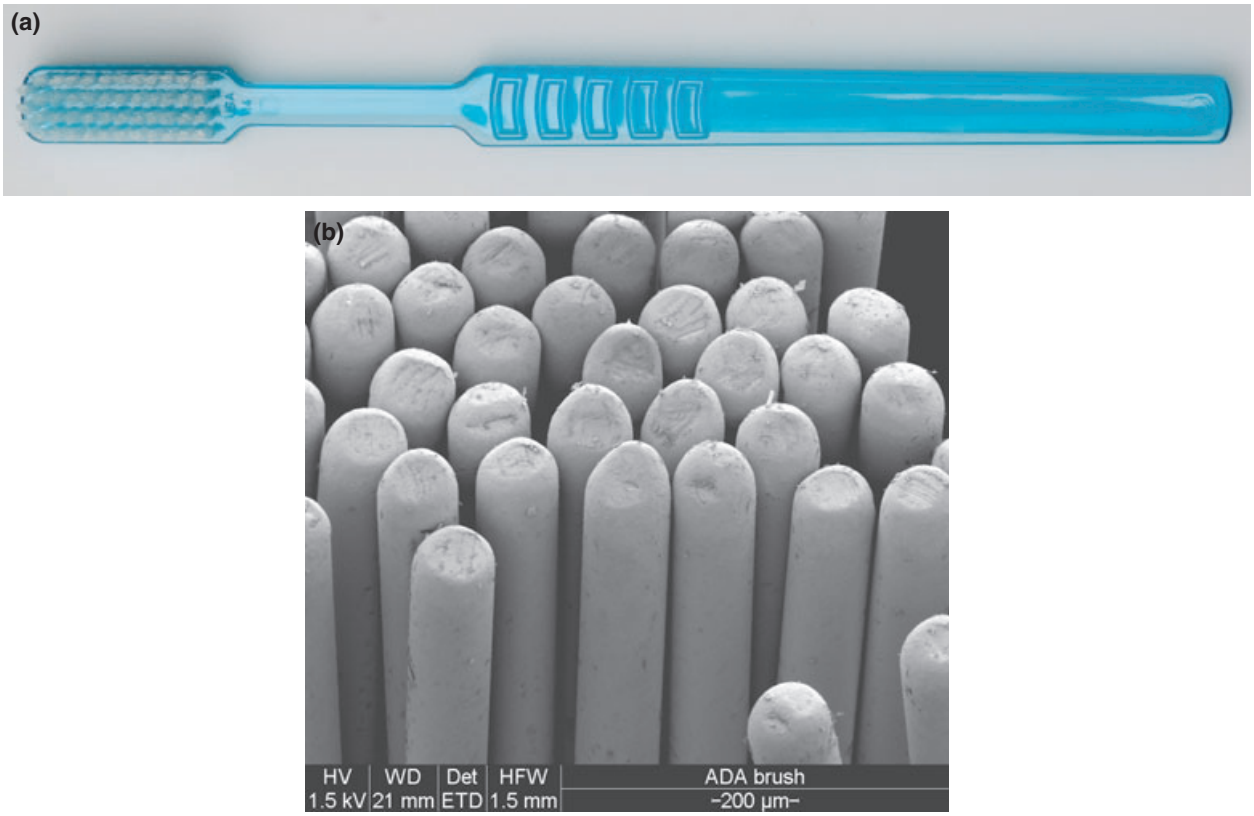


*Fig. 3.* (a) ADA-brush; (b) at 100× magnification.

each subject. Randomization of toothbrush allocation was performed using true random numbers (http://www.random.org).

### Session 1

Subjects were divided among two groups and were allowed to become familiar with their randomly assigned brush for at least 10 days. One group received the OBSA-brush and the ADA-brush. The other group received the SENS-brush and the ADA-brush.

During this period they brushed on alternate days with one of the two brushes according to a brushing calendar. The subjects were instructed to brush twice daily for 2 min on each occasion, for the duration of the trial (12 weeks). A standard, fluoride-containing dentifrice (Zendium fresh mint, RDA ± 76; Sara Lee DE International BV, Utrecht) was provided. After 2 weeks they returned for their first session. Subjects were asked to abstain from all oral hygiene procedures for 48 h, prior to this assessment, to allow plaque to accumulate and to resolve the abrasional effects of previous brushing exercises on the gingival tissues. Prebrushing plaque and gingival abrasion were assessed. Next one group brushed according to split-mouth design with the OBSA in two contra-lateral quadrants and as a control the ADA-brush in the two opposing contra-lateral quadrants (9). The other group brushed similarly with the SENS and the ADA. Post-brushing plaque and gingival abrasion were assessed. Subjects were provided with fresh toothbrushes according to a reversed assignment (cross-over). They crossed-over with their test brush being either SENS-brush or OBSA-brush but subjects continued using the ADA-brush. Subjects practiced on alternate days for at least 10 days and returned for session 2.

### Session 2

This session was identical to session 1 with the only exception being the reversed toothbrush assignment. Upon completion of the assessment subjects were given fresh toothbrushes and were ask to practice on alternate days with the SENS and OBSA. They returned after at least 10 days of practice.

### Session 3

This session was identical to session number 1 and 2. It differed with respect to the choice of brushes. This session

allowed for a head to head comparison of the two soft test brushes, the SENS-brush and the OBSA-brush.

## Assessments

For the assessment of gingival abrasion the gums were disclosed by Mira-2-Ton® disclosing solution for better visualization of areas where the surface of the oral epithelium had been abraded (Mira-2-Ton® Hager & Werken GmbH & Co. KG., Duisburg, Germany) (10, 11). Each quadrant was disclosed using a new cotton swab with fresh disclosing solution. The gingival tissues were divided into three areas marginal (cervical free gingiva), approximal (papillary free gingiva) and mid-gingival (attached gingiva), and the number and site location of any gingival abrasions then were recorded (excluding the third molar and central incisor regions. The rationale not to include central incisor regions was avoiding overlapping of adjacent quadrants during brushing (12). A PQ-William's periodontal probe (Hu-Friedy Mfg. Co., Inc. Chicago, IL, USA), placed across the long axis of the lesions, was used to measure the size of the abrasions. The greatest diameter of the abrasion lesion determines the size. The number of abrasion sites was scored according to the method as described by Van der Weijden *et al.* (13). The lesions were assessed as small (≤2 mm), medium (≥3 but ≤ 5mm) 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-Ton® (Hager & Werken GmbH & Co. KG., Duisburg, Germany), using the modification of the Quigley and Hein (14) index, as described in detail by Paraskevas *et al.* (15). Six sites per tooth were scored where the absence or presence of plaque was recorded on a scale 0–5 (0 = no plaque, 5 = plaque covered more than two-thirds of the tooth surface). After this baseline examination subjects brushed themselves with one allocated toothbrush in two randomly selected contra-lateral quadrants, whereas the remaining two quadrants were brushed with the alternative toothbrush. A timer was used to make sure that the brushing time per brush and per quadrant is 30 s, 15 for the buccal, and 15 for the lingual side (16, 17). All toothbrushing took place in a separate room from the examiner to retain blindness of the study. This was done in front of a mirror covered with a purple foil, so subjects were unable to see the disclosed areas of plaque (12). After a second disclosing with Mira-2-Ton®, the remaining plaque and gingival abrasions was re-assessed. Throughout the study all examinations were performed by one and the same examiner (PAV) under the same conditions. The examiner was blind to treatment randomization.

### Questionnaire

At the end of each session (1 through 3), all subjects received a questionnaire using a Visual Analogue Scale (VAS-scores) designed to evaluate their attitudes to the two assigned toothbrushes. Subjects were asked to mark out a point on a 10 cm long uncallibrated line with the negative extreme response (0) on the left and the positive extreme (10) at the right end reflecting their personal attitudes.

### Data analysis

The primary outcome variable for this study was the potential for each of the three brushes to cause gingival abrasion. As secondary outcome variable the efficacy to remove supra-gingival plaque and patient perception was evaluated. Mean values for both gingival abrasion and plaque were calculated for all sites, all vestibular sites, all lingual sites, vestibular sites, lingual sites, approximal vestibular sites and approximal lingual sites. Brushes were compared using the Wilcoxon test for matched pairs. Values of $P < 0.05$ were accepted as statistically significant. In case of a standard deviation of 4.9 it was possible to detect a difference of 1.6 in gingival abrasion indices with a power of >80% in a sample of 75 subjects.

## Results

The results are presented in Tables 1 and 2. With respect to abrasion, the SENS was more abrasive than the ADA ($P < 0.001$) while the OBSA was less abrasive than the SENS

Table 1. **Overall trauma-scores and increments from baseline to end**

| | *n* | Baseline | End | Diff (baseline–end) |
|---|---|---|---|---|
| *Comparison 1* | | | | |
| ADA | 76 | 3.8 (4.6) | 8.4 (6.3) | 4.6 (4.2) |
| Oral-B | | 3.7 (4.5) | 8.8 (6.1) | 5.1 (3.8) |
| *P*-value* | | *0.805* | *0.283* | *0.319* |
| 95% CFI | | −0.6 to 0.8 | −1.3 to 0.6 | −1.3 to 0.4 |
| *Comparison 2* | | | | |
| ADA | 76 | 3.4 (3.7) | 7.4 (5.3) | 4.0 (3.9) |
| Sensodyne | | 3.3 (3.7) | 9.8 (7.0) | 6.5 (5.6) |
| *P*-value* | | *0.791* | *0.002* | *<0.001* |
| 95% CFI | | −0.6 to 0.9 | −3.8 to −0.9 | −3.8 to −1.2 |
| *Comparison 3* | | | | |
| Oral-B | 76 | 4.3 (3.6) | 11.3 (5.7) | 7.0 (4.0) |
| Sensodyne | | 4.7 (4.1) | 15.2 (8.4) | 10.5 (6.5) |
| *P*-value* | | *0.290* | *<0.001* | *<0.001* |
| 95% CFI | | −1.0 to 0.2 | −5.4 to −2.4 | −4.9 to −2.1 |

Diff = Difference between products.
**P*-value Wilcoxon test.

Table 2. **Plaque-scores at baseline and end %, reduction (*n* = 76)**

| | Baseline | End | Reduction (%) |
|---|---|---|---|
| *Comparison 1* | | | |
| ADA | 2.25 (0.51) | 0.98 (0.38) | 56% (14%) |
| Oral-B | 2.25 (0.50) | 1.15 (0.41) | 49% (14%) |
| *P*-value | | *<0.0001** | *<0.001*** |
| 95% CFI | | −0.21 to −0.11 | 5% to 9% |
| *Comparison 2* | | | |
| ADA | 2.22 (0.44) | 1.01 (0.38) | 54% (16%) |
| Sensodyne | 2.24 (0.45) | 1.05 (0.39) | 53% (14%) |
| *P*-value | | *0.1114** | *0.291*** |
| 95% CFI | | −0.09 to 0.01 | −1% to 4% |
| *Comparison 3* | | | |
| Oral-B | 2.68 (0.38) | 1.35 (0.42) | 50% (14%) |
| Sensodyne | 2.66 (0.38) | 1.28 (0.42) | 52% (14%) |
| *P*-value | | *0.0131** | *0.028*** |
| 95% CFI | | 0.02 to 0.13 | −4% to −0.3% |

**P*-value repeated measures analysis, end-scores as dependent variables, baseline scores and session (for comparisons 1 and 2) as a covariate.
***P*-value Wilcoxon test.
No significant 'session effect' was found.

($P < 0.001$). There was no statistically significant difference between the OBSA and the ADA ($P = 0.319$). All three brushes showed statistically significant reductions (49–56%) in plaque versus baseline. Compared to the ADA and the SENS, the OBSA had a smaller percentage of plaque removal (56% versus 49%, $P \leq 0.001$; and 50% versus 52%, $P = 0.028$).

## Response to questionnaire

Subjects were asked whether they considered the brushes pleasant in use (0 = unpleasant in use, 10 = very pleasant). The average VAS-scores showed no difference between the comparisons OBSA–ADA and OBSA–SENS. However subjects rated the SENS higher than the ADA brush (7.2 versus 5.4, respectively, $P < 0.001$). Furthermore subjects were asked ('yes' or 'no') whether their teeth felt clean after brushing. For the three brushes the answer 'yes' ranged between 79% and 93% to this question. Only in the comparison OBSA–SENS a significant difference was observed where the SENS more frequently resulted in a more positive feeling of cleanliness (86.6% versus 89.6% respectively, $P = 0.016$). Subjects were asked whether they had the idea that the brush harmed their gum. No difference was observed between brushes. Finally subjects were asked which brush they would like to take home. In the comparison OBSA–ADA and SENS–OBSA no specific preference was observed, However in the comparison SENS–ADA, 75% of the subjects said they would take home the SENS.

## Discussion

As late as 1967, most people were buying hard brushes (18). The shift in preference to soft brushes of specific design paralleled the change that occurred in oral health care when calculus was the prime etiologic agent in periodontal disease (19). The concentration on plaque, especially in the crevicular area and the attention to intrasulcular brushing strongly influenced the change from hard to soft filaments, primarily because of the concern with trauma to the gingival tissues (20). Soft filaments are universally recommended for sulcular brushing such as the Bass-method (6, 21–25). Patients can brush at the cervical areas without fear of discomfort or soft tissue laceration (22).

The present study examined the effect of two soft manual toothbrushes (OBSA and SENS) with different filament and brush head designs with respect to gingival abrasion and plaque removing efficacy in relation to a flat trimmed medium manual reference toothbrush (ADA). The results showed that all three brushes removed significant levels of plaque versus baseline. The SENS caused more gingival abrasion compared to the OBSA-brush, but the OBSA had lower scores for amount of plaque removed than the ADA and SENS. The increase in number of gingival abrasions in the cross-over part of this study was smaller than in the head-to-head comparison. Differences such as this were also observed in previous studies (10, 26) It indicates that the behaviour of the participants is an important factor for the observed effect. Indeed the plaque reduction in the latter part of the study was also higher. These results underline that within this study model it is necessary to always add a control. The long-term significance of the results from this single-use crossover study needs to be explored in further research.

The characteristics of an effective toothbrush are prime functional properties of the filaments (27). The degree of hardness and stiffness of a toothbrush depends on the filament characteristics such as material, diameter and length. Today many manufacturers vary the length or diameter of the filaments mounted in the head. Toothbrushes with thinner filaments are softer while thicker filament diameters are stiffer and less flexible. But also the number of filaments per tuft determines the hardness of a toothbrush which in term will have an effect on the cleaning performance. Robertson and Wade (28) showed that subjects cleaned significantly better with medium and hard brushes than with a soft-bristled brush. Berdon *et al.* (29) found that a toothbrush with 0.18 mm diameter filaments was significant less effective ($P < 0.05$) in cleaning than were five brushes with larger diameter filaments

from the same manufacturer. Gibson and Wade (7) compared a toothbrush with 0.2 mm diameter filaments and another with 0.18 mm diameter filaments observed a trend that the 0.2 mm filaments cleaned the marginal gingiva more effectively. In a crossover study, Vowles and Wade (30) tested the differences between 0.13 and 0.28 mm filament diameter and found that plaque removal was significant better ($P < 0.001$) with the thicker 0.28 mm filaments were used with the roll technique for brushing on the facial and interproximal areas. It appears therefore that filaments must have a degree of stiffness to create sufficient abrasion to dislodge plaque deposits. For example, a brush with very thin filaments will merely stroke across the tooth and as a result of the lack of load will no longer clean (2).

The concern about use of toothbrush filaments relates primarily to the potential for hard and soft tissue abrasion. The end of a toothbrush filament can be cut bluntly or rounded. In the present study, the SENS appeared to cause more gingival abrasion as compared to the OBSA-brush. Although not assessed for the purpose of the study, the SEM pictures (see Fig. 1b, 2b, 2c and 3b) of the filament end-rounding of the study brushes may provide an explanation for this observation. The SENS clearly show sub-optimal end-rounding characteristics. Sharp edged and unacceptably rounded filament tips represent a greater threat to dental tissues. In an early study, Breitenmoser *et al.* (31) evaluated the effect of filaments' end form on the gingival surface. It was found that manual toothbrushes with cut filament ends resulted in significantly greater gingival lesions than rounded ends. Further research has shown in several studies that filaments with sharp edges can cause soft tissue injury. The depth of epithelial lesions caused by toothbrushing was influenced by the quality of filament-end-rounding (32). Non-end-rounded filament turned out to be about twice as abrasive to soft tissues as rounded filament tips (33). Danser *et al.*(10) evaluated two types of end-rounding and observed that the form to which the ends are rounded indeed had an effect on the incidence of abrasion but did not affect the plaque removing efficacy.

Soft, multi-tufted brushes are recommended based on their usefulness in both supra- and subgingival plaque disruption with minimal likelihood of soft and hard tissue trauma (34). They are universally considered preferable for sulcular brushing (22). Soft filament brushes are particularly recommended for brushing shortly after periodontal surgery; for patients in whom there is a highly inflamed gingiva; for patients with naturally finely textured atrophic or sensitive mucosa and for those patients whose lack of manual dexterity in using a brush may cause injury to the gingiva (35). Patient may change to a slightly harder toothbrush as they find it comfortable to do so until the medium grade is reached (36). Some people prefer medium-hard brushes because they feel that their teeth are cleaner after brushing with a stiffer brush (22). The present study shows that when there is no clinical indication for a soft toothbrush the professional advice in relation to effectiveness should indeed be a toothbrush of medium stiffness. Future studies could focus on finding the optimal filament stiffness in relation to maximum efficacy and minimal abrasiveness. However one should not address the topic of filament stiffness by itself but should also regard the brush–toothpaste interaction. The ability of a toothbrush to hold and move polish/abrasive over the toothsurface namely affects the amount of hard tissue abrasion (37).

## Conclusion

The present study which compared two soft toothbrushes showed that the OBSA caused less gingival abrasion compared to the SENS-brush with a marginal loss (2%) of efficacy.

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