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Brushing with and without dentifrice on gingival abrasion

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Abstract

Objectives: This study was designed to evaluate two factors possibly influencing incidence of gingival abrasion during toothbrushing: (1) the abrasiveness of a dentifrice and (2) the possible influence of feedback of oral sensory perception.

Material and Methods: For this purpose, two separate, single blind, randomized clinical experiments were performed. The two groups of subjects were requested not to brush their teeth 48 h, prior to the experiments. After staining with disclosing solution gingival abrasion sites were recorded as small ($\leqslant$5 mm) and large ($>$5 mm), both before and after brushing. The dentifrice experiment was a split-mouth design, including 36 subjects, brushing their teeth in two randomly selected contra-lateral quadrants, either with or without dentifrice, whereas the remaining two quadrants were brushed, using the alternative choice. The sensory perception feedback experiment was a full-mouth design, including 43 subjects and two separate brushing exercises with use of dentifrice. The first brushing-exercise was performed by a dental hygienist, excluding the feedback of oral sensory perception of the brusher. After a 4 weeks period of familiarization to the manual toothbrush, subjects brushed themselves in the same random order as the hygienist, using a fresh brush, thus including oral sensory perception.

Results: In the dentifrice experiment, the increment of small abrasion sites was 5.86 for brushing with and 5.75 without dentifrice. There was no statistically significant difference between brushing with and without dentifrice. Both with and without dentifrice, more small abrasions were found vestibular, (3.78 and 4.22, respectively) as compared with lingual (2.22 and 1.42, respectively) ($p = 0.027$, $p < 0.001$). In the sensory perception feedback experiment, the increment in small gingival abrasion sites was larger for the subjects brushing themselves (8.86) as compared with the professional brushing (2.94, $p < 0.0001$). Subjects caused more abrasion on the vestibular surfaces (6.28) as compared with the lingual (0.60, $p = 0.0001$), where the professional did not show this difference (vestibular: 1.88, lingual: 1.30, $p = 0.\ 1388$).

Conclusions: No statistically significant difference in the incidence of gingival abrasion was found between brushing with dentifrice or without dentifrice. Neither did oral sensory perception seem to affect the incidence of gingival abrasion.

Key words: dentifrice; gingival abrasion; toothbrush

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People brush their teeth for many reasons e.g. to feel fresh and confident, to have a nice smile, to avoid bad breath and to avoid disease. To this end, toothbrushing with dentifrice is the most commonly practised oral hygiene procedure in developed countries. However, it has been known for a long time that toothbrushing may have some unwanted effects on the gingiva and hard tooth tissues (Kitchin 1941). Clinical experience does support the idea, that with improper use, toothbrushing can cause superficial damage to the gingival tissues. Unfortunately there are relatively few studies in the dental literature concerning gingival lesions because of toothbrushing. Thus, to what extent oral hygiene procedures may traumatize the gingival tissues is not clear. Gingival abrasions as a result of brushing, are reversible localized epithelial lesions. These can be superficial lesions, puncture wounds or erosion of the epithelium, which may extend into the submucosa and expose the connective tissue. The visualization of such lesions can be facilitated by dyes such as toluene blue or erythrocin applied to the soft tissues (Breitenmoser et al. 1979, Niemi et al. 1986, Niemi 1987, Addy & Hunter 2003). It is unlikely that gingival abrasion is induced by a single factor. It is more probable, that several factors are involved, though they may not act either simultaneously or in equal proportions. One factor, which has been mentioned, to be related to gingival abrasion is brushing force. Differences in the size of the brushing forces originate from differences in the activity and type of muscles in the shoulder, upper arm, forearm, and palm of the hand that are involved in the respective brushing movements. Uenoyama & Inada (1990) evaluated the effect of oral sensory perception on the level of brushing force. They noted that force might be affected by factors related to oral sensory perception rather than muscle activities per se.

Interestingly, there has been little debate on the role of dentifrice in the abrasion of soft tissues. This is somewhat surprising when abrasion of dental hard tissues is almost entirely a function of dentifrice (Addy & Hunter 2003). Detergents in dentifrice, agitated over a mucosal surface, could enhance the removal of the protective salivary glycoprotein layer and exert cytotoxic action on the overlying epithelial cells (Addy 1998). It would therefore not be stretching the realms of imagination to expect that the brush–dentifrice interaction is important to soft-tissue damage. (Addy & Hunter 2003). The present study was therefore designed to evaluate two factors that might influence the incidence of gingival abrasion during toothbrushing: (1) the abrasiveness of a dentifrice and (2) the possible influence of feedback of oral sensory perception.

Material and Methods

The study consisted of two separate experiments. In the first experiment the effect of the use of dentifrice on gingival abrasion was investigated. In the second experiment the influence of the sensory perception feedback mechanism on gingival abrasion was studied. For both experiments healthy subjects including both genders were recruited from non-dental students of the University. The volunteers were informed about the study, first in a recruitment letter and then again at the first appointment. They were given written explanation of the background of the study, its objectives and their involvement. All were requested to give their written consent before entering the study. The participants were screened for their suitability. The selection criteria were: good general health and a minimum of five teeth in each of the four quadrants. Exclusion criteria were: previous, routine use of a powered toothbrush, presence of orthodontic banding, removable partial dentures, oral lesions or probing pocket depth >5 mm, mental handicap or a physical handicap that restricted free movement of the hands or fingers.

Study design

The experiments were designed as single blind, randomized clinical studies.

Prior to all experiments, subjects were requested not to brush their teeth 48 h. prior to attending the examination. 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 number and site location of the gingival abrasions were then recorded on a Case Record Form, with the exclusion of the third molar and central incisor regions from the data analysis. The rationale not to include central incisor regions is avoiding overlapping of adjacent quadrants during brushing. These measurements will be referred to as pre-brushing abrasions. A William's periodontal probe, placed across the long axis of the lesions, was used to measure the size of the abrasions. The number of abrasion sites was scored according to the method as described by Danser et al. (1998a). Measurements were rounded off to the nearest millimeter mark on the probe. The gingival tissues were divided into three areas: marginal (cervical-free gingiva), inter-dental (papillary-free gingiva) and mid-gingival (attached gingiva). In the upper jaw the palatal mid-gingival area comprises the whole hard palate. The lesions were recorded as small ($\leqslant 5$ mm) and as large (>5 mm) using the greatest diameter of the abrasion lesion to determine the size. In both experiments subjects brushed their teeth under supervision. This was done in front of a mirror that was covered with a blue foil so that subjects were unable to see the disclosed areas of plaque. The subjects were guided through the 2 min. brushing exercise. A timer was used to keep track of the brushing time. One examiner (M. P.) was responsible for all gingival abrasion scores. Toothbrushing took place in a room separate from the examiner to retain blindness of the study.

Dentifrice experiment

This split-mouth study included a group of 40 subjects. The subjects brushed their teeth for 60 s in two randomly selected contra-lateral quadrants with a manual toothbrush (Butler Gum 411, containing 11 rows of tufts, most of the rows with four tufts (McKeen Productions Ltd, Ottawa, Canada) at random either with or without dentifrice (Elmex®, GABA, Almere, Holland, RDA $= \pm 77$). In a random order, either the first and third quadrants or the second and fourth quadrants were brushed. The two remaining quadrants were brushed for another 60 s, using the alternative choice of either with/without dentifrice. Thus the brushing time for the whole mouth was 2 min. When dentifrice was used, 0.25 ml fresh dentifrice was applied on the toothbrush for each surface of a quadrant (buccal or lingual/palatinal). Consequently in total 1 ml was used for the two assigned quadrants. Subjects expectorated the dentifrice foam and rinsed thoroughly with water. If brushing with dentifrice was the first assignment, the brush was thoroughly rinsed to remove remnants of dentifrice. Before and after brushing, gingival abrasion was assessed.

Sensory perception feedback experiment

For this study a new group of 43 subjects was used in which two separate brushing exercises were performed. During the first brushing exercise the whole dentition of each subject was brushed professionally by a dental hygienist. This was considered to exclude the feedback of oral sensory perception of the brusher. In a random order the four quadrants were brushed. Each quadrant was brushed for 30 s, which equals a brushing time for the whole mouth of 2 min. Subsequently gingival abrasion was scored again. Thereafter the subjects were handed the manual toothbrush for familiarization. Both verbal and written instructions in the use of the manual toothbrush were given together with a practical demonstration using a model. The subjects were instructed to use the brush at home, for the duration of the next 4 weeks brushing twice daily and for 2 min. on each occasion. After assessing the amount of pre-brushing abrasions, the subjects brushed themselves using a fresh brush in combination with the dentifrice. In the same random order as in the professional brushing exercise the four quadrants were brushed. This was considered to include the feedback of oral sensory perception to the brusher.

Data analysis

The total numbers of abrasion sites were calculated, resulting in overall numbers of small and large abrasions, respectively. Furthermore, separate numbers were calculated for inter-dental, cervical and mid-gingival areas as well as lingual and vestibular aspects. These latter data were used for explorative analyses. The two experiments in this study differed with respect to the number of teeth that were assessed within each patient for the purpose of the study. In the first experiment using the split-mouth design, for each treatment two quadrants were used. The second experiment used a full mouth assessment. Therefore the total number of abrasion sites for the first experiment should be multiplied by 2 to get a full-mouth equivalent. Wilcoxon-tests were used for comparisons within each experiment. Values of $p < 0.05$ were accepted as statistically significant. The study sample was determined in a way, that, when allowing for a standard deviation of the difference in abrasion sites (both between with and without dentifrice and between professional and panellist brushing) of five small lesions, the study had a power of $>80\%$ to discern a difference of three to four lesions. A sample size of $n = 30$ would have been sufficient to result in statistical significance at a level of $\alpha < 0.05$. In cases where no significant difference was found, 95% confidence intervals of the differences were calculated.

Results

Dentifrice experiment

From the 40 enrolled subjects, 36 subjects completed the study (12 male, 24 female, mean age 23.9 years, range 18–43 years). Four subjects failed to meet the final appointment for reasons not deemed to be related to the study protocol. The results of the gingival abrasion scores are presented in Table 1a and 1b. The mean half mouth pre-brushing levels were 2.08–2.39 for small sites with and without dentifrice, respectively. Most pre-brushing abrasion is observed at the mid-gingival site. The increase in small abrasion sites was 5.86 and 5.75 for brushing with and without dentifrice, respectively. Large sites of gingival abrasion were not a common finding in both brushing exercises; the incidence was 0.11 sites for both quadrant sets. No statistically significant difference in incidence of gingival abrasion between brushing with and without dentifrice was found. Explorative analysis comparing vestibular and lingual surfaces was performed for small abrasions. Results show that brushing causes more small abrasions on the vestibular both with and without dentifrice (3.78 and 4.22, respectively) as compared with the lingual aspect of the gingiva (2.22 with and 1.42 without dentifrice). This difference was statistically significant both for brushing with and without dentifrice ($p = 0.027$ and $p < 0.001$, respectively)

Sensory perception feedback experiment

All 43 subjects completed the study (eight male, 35 female, mean age 21.6 years, range 18–26 years). The results of the second experiment are presented in Table 2a and 2b. The mean (full mouth) results of pre-brushing levels for small sites of gingival abrasion were 2.93 and 1.93 for professional and panellist brushing, respectively. The increase in small gingival abrasion sites is larger if the subjects brush themselves as compared with the professional brusher (8.86 and 2.94, respectively, $p < 0.0001$). Explorative analysis revealed that this difference is mainly the result of a higher incidence at cervical and mid-gingival surfaces. The mean difference in abrasion as separated for vestibular and lingual surfaces shows that the panellist causes more abrasion on the vestibular surfaces (6.28) as compared with the lingual (0.60). For the professional brusher there was no significant difference between vestibular (1.88) and lingual (1.30, $p = 0.1388$).

Discussion

The present study examined the influence of several factors on gingival abrasion as a result of toothbrushing. Recording of gingival abrasion is difficult. When using normal oral inspection, visible gingival abrasion is not a common finding in toothbrushing experiments (Van der Weijden et al. 1993, Heasman et al. 1999). Heasman et al. (1999) evaluated the incidence of visual abrasion after use of manual and powered toothbrushes, out of 225 assessments only in three assessments were visual abrasions observed. A great many subjects would be needed to establish differences if brushes are compared. Therefore several other methods have been used to evaluate gingival abrasion (Van der Weijden & Danser 2000, Van der Weijden et al. 2002). One approach is by means of scanning

Table 1a. Mean scores for small gingival abrasions after panellist brushing with and without dentifrice, assessed in two quadrants after 1 min of brushing ($n = 36$)

Sites	All sites	Inter-dental	Cervical	Mid-gingival
Without dentifrice				
Pre-brushing	3.03 (4.55)	0.17 (0.56)	0.19 (0.53)	2.67 (4.24)
Post-brushing	8.78 (7.12)	2.25 (2.49)	2.67 (3.05)	3.86 (5.37)
Differences	5.75 (4.37)*	2.08 (2.31)	2.47 (3.02)	1.19 (2.05)
With dentifrice				
Pre-brushing	2.83 (6.31)	0.22 (0.54)	0.03 (0.17)	2.58 (5.95)
Post-brushing	9.22 (8.05)	2.03 (2.25)	3.00 (3.04)	4.19 (5.69)
Differences	6.39 (4.86)*	1.81 (2.27)	2.97 (3.01)	1.61 (1.70)

Standard deviation in parentheses. *$p = 0.253$, (Wilcoxon-test comparing without and with dentifrice). 95% CFI of difference (without *versus* with dentifrice): $-2.27 < > 0.99$.

Table 1b. Mean scores for large gingival abrasions after panellist brushing with and without dentifrice, assessed in two quadrants after 1 min of brushing ($n = 36$)

Sites	All sites	Inter-dental	Cervical	Mid-gingival
Without dentifrice				
Pre-brushing	0.06 (0.23)	0.00 (0.00)	0.00 (0.00)	0.05 (0.23)
Post-brushing	0.17 (0.51)	0.00 (0.00)	0.08 (0.37)	0.08 (0.37)
Differences	0.11 (0.40)*	0.00 (0.00)	0.08 (0.37)	0.03 (0.17)
With dentifrice				
Pre-brushing	0.03 (0.17)	0.00 (0.00)	0.00 (0.00)	0.03 (0.17)
Post-brushing	0.14 (0.54)	0.00 (0.00)	0.03 (0.17)	0.11 (0.52)
Differences	0.11 (0.40)*	0.00 (0.00)	0.03 (0.17)	0.08 (0.37)

Standard deviation in parentheses. *$p = 1.000$ (Wilcoxon-test comparing without and with dentifrice). 95% confidence interval of difference (without *versus* with dentifrice): $-0.16 < > 0.16$.

Table 2a. Mean scores for full mouth small gingival abrasions after brushing with and without oral sensory perception (i.e. panellist and professional, respectively, with dentifrice, $n = 43$)

Sites	All sites	Inter-dental	Cervical	Mid-gingival
Brushing without sensory perception (first session)				
Pre-brushing	2.93 (3.71)	0.05 (0.31)	0.02 (0.15)	2.86 (3.68)
Post-brushing	5.88 (4.74)	0.72 (1.35)	1.05 (1.43)	4.07 (3.69)
Differences	2.95 (2.94)*	0.67 (1.15)	1.02 (1.44)	1.21 (1.68)
Brushing with sensory perception (second session)				
Pre-brushing	1.93 (2.74)	0.02 (0.15)	0.02 (0.15)	1.88 (2.65)
Post-brushing	10.79 (6.25)	1.09 (1.41)	3.35 (3.39)	6.30 (4.80)
Differences	8.86 (5.73)*	1.07 (1.35)	3.33 (3.41)	4.42 (4.03)

Standard deviation in parentheses. $^{*}p < 0.001$ (Wilcoxon-test comparing without and with sensory perception).

Table 2b. Mean scores for full-mouth large gingival abrasions after brushing with and without oral sensory perception (i.e. panellist and professional, respectively, with dentifrice, $n = 43$)

Sites	All sites	Inter-dental	Cervical	Mid-gingival
Brushing without sensory perception (first session)				
Pre-brushing	0.09 (0.29)	0.00 (0.00)	0.00 (0.00)	0.09 (0.29)
Post-brushing	0.30 (0.60)	0.02 (0.15)	0.12 (0.45)	0.16 (0.37)
Differences	0.21 (0.56)*	0.02 (0.15)	0.12 (0.45)	0.07 (0.26)
Brushing with sensory perception (second session)				
Pre-brushing	0.26 (1.09)	0.00 (0.00)	0.16 (1.07)	0.09 (0.29)
Post-brushing	0.30 (0.80)	0.00 (0.00)	0.21 (0.71)	0.09 (0.29)
Differences	0.05 (0.31)*	0.00 (0.00)	0.05 (1.31)	0.00 (0.00)

Standard deviation in parentheses. $^{*}p = 0.425$ (Wilcoxon-test comparing without and with sensory perception). 95% confidence interval of difference (without *versus* with sensory perception): $-0.25 < > 0.57$.

electron microscopy (SEM) as described by Hasegawa et al. (1994). Impressions of the teeth and gingiva were assessed with SEM. This proved to be a time-consuming method and it is difficult to quantify the amount of abrasion. Breitenmoser et al. (1979) have found that a commercially obtained plaque disclosing solution Dis-Plaque could excellently stain the lesions and these could be easily distinguished from the normal gingiva. This finding was confirmed for another solution (Mira-2-Tone®) by Danser et al. (1998a). In the present study this sensitive method of staining was used to highlight minor areas of gingival abrasion that would otherwise have been largely undetectable. Before staining the areas with Mira-2-Tone® solution the small sites of abrasion were not clinically visible. Recording the area where the abrasions were found (inter-dental, marginal and mid-gingival aspects of the gingiva) further refined this method. The size of the lesion is taken into account, differentiating between small and large abrasions. The presence of gingival abrasions at baseline, that can be observed with disclosing agent after 48 h of abstention of oral hygiene measures, is a normal finding (Danser et al. 1998a). Interestingly in previous studies the increase in abrasion is most often found as small lesions at the mid-gingival aspect (Van der Weijden 2002). The present data confirm this observation. The observation by itself can be explained by the actual size of the surface area of the inter-dental, marginal and mid-gingival aspect. The mid-gingival aspect is by far the largest.

In the literature, several factors related to gingival abrasion have been suggested such as abusive toothbrush use (Smukler & Landsberg 1984, Addy & Hunter 2003), manual or powered toothbrushing (Niemi 1987), toothbrush grip (Niemi et al. 1987), brush head shape (Niemi et al. 1986), stiffness of bristles (Niemi et al. 1984), end-rounding of toothbrush bristles (Breitenmoser et al. 1979), daily toothbrush frequency (Sangnes & Gjermo 1976, Khocht et al. 1993). The simple act of removing deposits from teeth requires that the toothbrush–dentifrice combination possesses some level of abrasiveness. Filaments must have a degree of stiffness to create sufficient abrasion to dislodge plaque deposits. This stiffness has to be balanced against potential detrimental effects to dental hard and soft tissues. It has been stated that hard-tissue damage is mainly caused by the abrasives in the dentifrice, whereas lesions of the gingival tissues are caused by the toothbrush (Meyers et al. 2000). This statement by Meyers et al. (2000) was based on SEM quantification of gingival abrasion, a method which has its limits as described above (Hasegawa et al. 1994). The method of recording gingival abrasion using the staining method gives a sensitive and quick tool to evaluate the earlier findings by Meyers et al. (2000). The dentifrice experiment of the present study evaluated the effect of dentifrice on abrasion of the gingival tissues on top of brushing with a toothbrush. It was investigated if there is a difference in incidence of gingival abrasion between brushing with and without a dentifrice. It was observed that the use of dentifrice with its abrasive ingredients and detergents did not induce an extra number of abrasion sites. This is in agreement with Alexander et al. (1977). They used hamster cheek pouch tissue, which was brushed mechanically for various intervals. The detection of protein removed during brushing was used as an index of tissue abrasion. The results showed that the dentifrice-polishing agent applied to the tissue with a brush did not increase the abrasive effect of the brush. In the study by Meyers et al. (2000) the effect of three commercially available dentifrices on tooth and gingival surfaces was investigated by means of SEM quantification. The results indicated that none of the dentifrices tested was harmful to teeth or soft tissues. The present data corroborate these earlier findings showing that there appears to be no relation between the use of dentifrice and gingival abrasion.

The data from the present study suggest that differences exist between the subjects participating in the two experiments. It can be calculated that on the basis of a full-mouth score the panellists in the dentifrice experiment would have $2 \times 2.83 = 5.66$ small pre-brushing abrasions compared with 2.93 and 1.93 in both episodes of the sensory perception experiment. The increase in the number of small abrasions after panellist brushing was greater in the panellists of the dentifrice experiment than in the sensory perception experiment (full-mouth equivalent $2 \times 6.39 = 12.78$ increment in small abrasions in dentifrice group as compared with 8.86 for the panellists of the sensory perception experiment). The most probable explanation for this discrepancy may be attributed to a learning effect. It has been shown that a learning period has an effect with respect to the incidence of gingival abrasion. In a study by Van der Weijden et al. (2002) a decrease of 60–75% in incidence of gingival abrasion after 4 weeks of familiarization with powered toothbrushes was found. In the dentifrice experiment the panellists were not allowed a familiarization period, but were entered immediately into the experiment without further previous training. In the sensory perception experiment the panellists went through a 4 weeks familiarization period after a professional instruction, resulting in an approximately 25% lower score of increase in trauma and over 60% lower number of pre-brushing abrasion sites. This is in accordance with the findings of Van der Weijden et al. (2002). The results of the sensory perception feedback experiment indicated that the subjects who brushed with a feedback of oral sensory perception caused more gingival abrasion than the professional who brushed without this feedback mechanism. A possible explanation could be that the professional brusher used a different brushing force as compared with the panellists. However previous research showed that there is no linear correlation between brushing force and abrasion (Danser et al. 1998b). Another explanation could be that the professional brusher was more successful in reaching the tooth surface resulting in less contact area between the toothbrush and the gingival tissues. Hereby, the risk of inducing gingival abrasion would be diminished. This assumption is substantiated by the finding that the panellists cause more abrasion on the vestibular surfaces as compared with the lingual whereas for the professional the number of abrasion sites was not different between vestibular and lingual aspects. These results suggest that visual control and professional skill are probably more important than the feedback of oral sensory perception in preventing imprecise brush placement and overzealous brushing movements as a cause of gingival abrasion.

In summary, the present study was designed to evaluate two factors that might influence the incidence of gingival abrasion during toothbrushing: (1) the abrasiveness of a dentifrice and (2) the possible influence of feedback of oral sensory perception. The results showed that there is no statistically significant difference in the incidence of gingival abrasion between brushing with dentifrice or without dentifrice. Neither did oral sensory perception seem to affect the incidence of gingival abrasion. Sensory perception is most probably overruled by individual dexterity, professional skill and visual control.

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