Evaluation of the incidence of gingival abrasion as a result of toothbrushing


Abstract. The aims of the present study were: (1) to establish the incidence of gingival abrasion as a result of toothbrushing, using a manual and electric toothbrush; (2) to establish the influence of filament end-rounding on the incidence of gingival abrasion and the efficacy of toothbrushing; (3) to assess whether the speed of the electric brush has a feedback-effect on the brushing force used and to correlate the incidence of gingival abrasion with force. Two experiments were carried out. In the first experiment, 50 subjects brushed for 3 weeks every other day with either a manual (Butler 411) or an electric toothbrush (Braun/Oral-B Ultra Plaque Remover-D9). All received brief instructions and were asked to abstain from oral hygiene 24 hrs before their appointment. After disclosing the teeth and gums with Mira-2-Tone solution, plaque and gingival abrasion were assessed. Next, the panellists brushed in a random split-mouth order. After brushing and a second disclosing, plaque and abrasion were re-assessed. The results showed that the incidence of gingival abrasion was comparable for the manual and the D9. Using a similar design as in experiment no. 1, in experiment no. 2 a new group of 47 subjects brushed for 3 weeks alternating between the Braun/Oral-B Plaque Remover-D7 and D9. At the appointment, the subjects first brushed in a split-mouth order with the D9 with 2 different types of endrounding. Plaque and abrasion were assessed. Immediately following this brushing exercise, the subjects rebrushed with the D7 (2800 rot/min) and the D9 (3600 rot/min) during which brushing force was measured. The results of this experiment showed that endrounding has no effect on plaque removal but does effect the incidence of gingival abrasion. Brushing force is not influenced by the speed of the brushhead and no correlation with the incidence of gingival abrasion was observed. In conclusion, the results of this study show that gingival abrasion is not influenced by brushing force, but is affected by filament endrounding.

Key words: gingival abrasion; electric and manual toothbrush; filament end-rounding.

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In the prevention of oral diseases, proper oral hygiene is of foremost value. Unfortunately, several problems are encountered when thorough oral hygiene is performed. Due to improper brushing techniques, abrasive toothpaste and hard bristle filament strips people with regular tooth brushing habits sometimes damage the gingiva, the dentin or enamel. They may develop marginal ulceration of the gingiva, gingival recession, exposure of root surfaces and esthetical problems (Sandholm et al. 1982, Vehkalaiti et al. 1989). The most common of these findings is the local recession of the gingival margin (Sandholm et al. 1982, Khocht et al. 1993).

Epstein & Tainter (1943) described several variables that affect toothbrush abrasion of which were brushing pressure and bristle type directly related to the brushing itself. The stiffness and unfavourable shape of toothbrush bristles have been claimed to be an etiologic factor in the origin of gingival injury (Hirshfeld 1931, Lange 1977). Breitenmoser (1979), studying the damaging effect of toothbrush bristle-end form on the gingiva, concluded that with standardized brushing forces, cut bristle ends were more damaging than rounded ends.

Next to hand toothbrushes, electric toothbrushes are of great value in the instruments people use for oral hygiene. Since 1960, a continuous development of different electric toothbrushes can be seen. A number of studies have been presented concerning the efficacy of electric toothbrushes, with regard to plaque removal. The results of these studies suggest that electric brushes
provide additional benefit compared to manual brushes (for review: Hancock 1996, Saxer & Yankell 1997, Walmsley 1997). Little information regarding gingival abrasion due to toothbrushing with an electric toothbrush appears to be present. Therefore, the objectives for this study were: 1. to establish the potential of a manual and electric toothbrush to cause gingival abrasion; 2. to establish the influence of filament endrounding on the incidence of gingival abrasion and the efficacy of toothbrushing; 3. to assess whether the speed of the electric brush has an effect on the brushing force used and to correlate the incidence of gingival abrasion with force.

Material and Methods

Study 1

Subject selection
50 healthy panelists of both sexes were recruited from non-dental students of the University. The volunteers were informed, first in a recruitment letter and then secondly at the first appointment. They were given written explanation of the background of the study, its objectives and their involvement. They all were requested to give their written consent before entering the study. All 50 participants entered into this study after having been screened for their suitability. The selection criteria were: a minimum of 6 teeth in each of the 4 quadrants and no pockets >4 mm. Exclusion criteria were: presence of orthodontic banding, removable partial dentures, oral lesions or periodontal problems. Plaque and calculus were removed by a dental hygienist and the teeth were polished, so that all subjects started with equally clean teeth.

Study design (Manual versus electric)
This study was designed as a split-mouth, single blind, randomised clinical study. All subjects received the Braun Oral-B Ultra Plaque Remover® (D9) with the EB9 brushhead, a manual toothbrush (Butler 411®) and a standard fluoride toothpaste (Zendium® rda=60) (rda=relative dentin abrasion, Hefferren 1976). All subjects were instructed briefly how to use the two different brushes. The aim of this short instruction was only to familiarize the subjects with the 2 brushes attempting not to influence habitual brushing methods. They were instructed to use each toothbrush every other day for the next three weeks to establish a familiarity with each toothbrush prior to the start of the experiment. A brushing calendar was supplied so that they knew which brush to use. They were requested not to brush their teeth 24 h prior to attending the examination. At this visit both the gums and teeth were disclosed by Mira-2-Tone® solution (Hager & Werken, GMBH & Co. Düsseldorf, Germany). Mira-2-Tone® solution was used for better visualisation of areas where the surface of the oral epithelium has been damaged. Gingival abrasion present on the tooth related soft tissues was assessed and recorded using the method adapted from Brettensomer et al. (1979). Abrasion sites were scored as small (≤5 mm) or large sites (>5 mm). The tooth related soft tissues were divided into three areas: cervical, interdental and mid-gingival as can be seen in Fig. 1. The mid-gingival area comprised the gingival tissues up to the muco-gingival junction. In the upper jaw this area comprised the whole palate. Plaque was assessed according to the Quigley & Hein index at 6 sites per tooth (Volpe et al. 1993). Next the participants brushed for 60 seconds with their first assigned brush (being either the Braun Oral-B Ultra Plaque Remover® (D9) or the Butler 411®) in 2 randomly selected contra-lateral quadrants. Brushing was repeated (another 60 s) with the 2nd brush on the opposing 2 contra-lateral quadrants. Thus, brushing time for the whole mouth was 2 min. All toothbrushing included Zendium® dentifrice and took place in a separate room from the examiner to retain blindness of the study. This was done in the absence of a mirror so that subjects were unable to see the disclosed areas of plaque. After a second disclosing with Mira-2-Tone® the remaining plaque and visible gingival abrasions were reassessed.

All clinical examinations were performed by the same examiner (MD) using the same dental unit and operating lamp. At the time of examinations the examiner was unaware of the brush type used. Records of earlier examinations were not available to the examiner at the time of re-examination. The third molars if present and central incisors were excluded from the recordings.

Study 2

In this study, 2 experiments were completed: one designed to evaluate the effects of toothbrush bristle endrounding on gingival abrasion and another designed to evaluate the effects of brush-handle speed on brushing force.

Subject selection
A second group of 50 subjects was selected according to the same criteria as presented above. This time the subjects received two electric toothbrushes, the Braun Oral-B Plaque Remover® (D7) and the Braun Oral-B Ultra Plaque Remover® (D9) and were instructed in the same way as in the previous experiment. The Braun Oral-B D9 was used in the endrounding experiment and the Braun D7 for the force experiment.

Effect of endrounding on gingival abrasion
Fig. 2 illustrates the 2 types of endrounding. The form of endrounding designated as "roman" represents a more or less flat end of the filament with rounded edges. The form designated "gothic" represents a filament which has a rounded pointy end. Again after 3 weeks of familiarisation using a brushing calendar, subjects returned for evaluation having abstained from brushing for 24 h. Plaque and gingival desquamation was scored by Mira-2-Tone® solution. Subjects then brushed with the Braun Oral-B Ultra Plaque Remover (D9) and in two contra-lateral quadrants using the randomly assigned "roman" or "gothic" brushhead. After brushing with each brushhead for 60 s, teeth and gums were again disclosed and reassessed.

Effect of brush-handle speed on brushing force
Immediately following the assessment of plaque removal and gingival abra-
Gingival abrasion as a result of toothbrushing

Fig. 2. This photograph shows the two endroundings of the brushheads. On the left side the “roman-shaped” endrounding is shown and on the right side the “gothic-shaped” endrounding.

Fig. 3. Examples of sites of gingival abrasion after brushing by panelists, made visible after disclosing with Mira-2-Tone®. Small and large sites of abrasion can be seen.

The subjects rebrushed to determine the brushing forces used during their normal brushing regime. The Braun Oral-B Plaque Remover® (D7) and the Braun Oral-B Ultra Plaque Remover® (D9) handle were used in 2 contra-lateral quadrants (2×60 s) as previously described. The handles were both used with an EB9 brushhead equipped with a strain gauge which recorded through a computer set-up the amount of force used while brushing. All force measurements were recorded by the same examiner (GAW).

**Force measurements**

Brushing force was measured using a computer set-up (see Van der Weijden et al. 1996). A double strain gauge (Kyowa electronic instruments Co. Ltd; KFWS-2-120-D16-11L3M2S) was glued to the handle of the toothbrush. One strain gauge element was aligned to the longitudinal axis of the brush and used to measure force. The other gauge element was set perpendicular to the axis to balance for temperature changes. Elongation of the gauge element by bending of the brush handle produces a change in electrical resistance. These changes can be read by a computer.

The strain gauge was attached to a strain amplifier which in turn was attached to a computer. The computer recorded the voltage from the amplifier (100 Hz) and calculated the mean brushing force. Before each measurement, calibration was performed with a standard force of 300 g, applied at the midpoint of the bristle section.

**Statistical analysis**

The average index score was determined for each individual. The percentage plaque reduction was calculated by dividing the difference between base and end scores by the baseline scores. Brushing was compared using the Wilcoxon paired non-parametric test. The data of the trauma assessment were analyzed using the Wilcoxon with baseline trauma scores as a covariate. Multiple Regression Analysis was used to detect possible correlations. Values of \( p<0.05 \) were accepted as statistically significant.

**Results**

**Manual versus electric toothbrush**

The mean baseline plaque scores at all sites were 1.84 for the D9 and 1.81 for the manual toothbrush (Table 1). No statistically significant differences were found for these baseline indices. Before brushing with the D9 and the manual brush, 34 and 36 subjects resp. showed presence of small sites of gingival abrasion (Fig. 3); after brushing this was 39 and 44 subjects resp. (Table 2). Large sites of gingival abrasion were seen less frequently: in 6 and 14 subjects before brushing with the D9 and the manual brush resp. and in 9 and 18 subjects after brushing. The mean gingival abrasion scores for the D9 and the manual brush at baseline for sites <5 mm were 3.85 and 3.31, respectively, and for sites >5 mm it was 1.67 for the D9 and 1.71 for the manual brush (Table 2). No differences were found for the amount of large sites with gingival abrasion before and after brushing. Ne-

<table>
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<th>Post-brushing</th>
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Table 1. Mean values of the Quigley & Hein Plaque Index before and after brushing by the panelists (n=47); standard deviation in parentheses

Table 2. Number of subjects showing a site of gingival abrasion, the mean number of small (<5 mm) and large sites of gingival abrasion (>5 mm) with the standard deviations before and after brushing using the D9 and the manual toothbrush (n=47)
ther were differences found in the amount of small sites of gingival abrasion after brushing with the D9 when compared to the manual brush (Table 2). Detailed information about the number of subjects showing the small and large sites of gingival abrasion per tooth type and per quadrant is given in Table 3. More small abrasions could be found in the upper jaw compared to the lower jaw. The majority of small abrasions in the upper jaw were found at the midgingival area (Fig. 2).

In order to establish whether the incidence of gingival abrasion was related to efficacy, the percentage plaque reduction was correlated with the increase of gingival abrasion. No significant relationship was observed.

### Endrounding

The mean baseline plaque scores at all sites were 1.76 for the quadrants used to brush with the D9 with the gothic-shaped brushhead and 1.71 for the D9 with the roman-shaped brushhead (Table 4).

Before brushing with the D9 with either the “gothic” or the “roman” endrounding 34 and 37 subjects, respectively, showed presence of small sites of gingival abrasion; after brushing the number of subjects increased to 47 for both endroundings. Large sites of gingival abrasion were seen less frequently: in 6 and 5 subjects before brushing with the “gothic” and the “roman” endrounding, respectively and in 9 and 6 subjects after brushing. The mean pre-brushing abrasion scores for the brushheads with the “gothic” and “roman” endrounding were comparable both for sites ≤5 mm (4.03 and 4.08 resp.) as well as for sites >5 mm (1.17 and 1.60, respectively, Table 5). After brushing significantly more small sites of gingival abrasion (≤5 mm) were found than before brushing (p=0.02). No increase was found for the amount of larger sites with gingival abrasion before and after brushing. More small sites of gingival abrasion were found after brushing with the “gothic” endrounding compared to the “roman” endrounding. In Table 6, detailed information is given about the number of subjects showing small and large sites of gingival abrasion per tooth type and per quadrant.

In order to establish whether the incidence of gingival abrasion was related to efficacy in this experiment, the % plaque reduction was correlated with the increase of gingival abrasion. No significant relationship was observed.

### Force experiment

The mean force of brushing with the D7 (2800 rot/min) was 171 g and with the D9 (3600 rot/min) 169 g. No differences in force were found between the different areas (proximal, buccal or lingual) or between the two different brushes. The mean maximum scores ranged between 54 and 304 g (Table 7). Multiple regression analysis showed no correlations between the forces used with the D9 and efficacy. Neither was there a relationship between toothbrushing force and the incidence of gingival abrasion.

### Discussion

In the dental literature, only a few studies concerning gingival lesions due to toothbrushing have been reported. The lack of control of the frequency and force of brushing and also the exact criteria for the observations do not permit definite conclusions to be drawn. Several methods are used to describe gingival abrasion. One way of describing these lesions is by means of scanning electron microscopy (SEM).
study by Sandholm et al. (1982) revealed that brushing may in many cases result in moderate to severe abrasion of the gingiva. All subjects participating in their study were brushed by one dental hygienist using hard and soft manual toothbrushes. Clinical evaluation (visual) and SEM findings were found to correlate significantly although discrepancies between the two classification systems were also observed. Niemi et al. (1986) investigated gingival injury caused by standardized brushing. An examiner scored the visible gingival abrasion and the consistency of this examiner was ascertained to be 90% compared to SEM analysis. In the present study, Mira-2-Tone® solution was used as disclosing agent for the assessment of gingival abrasion. Breitenmoser et al. (1979) investigated the use of a disclosing agent for the identification of gingival abrasions. They found that a commercially obtained plaque disclosing solution Dis-Plaque (Dis-Plaque, Pacemaker Corporation, P.O. Box 16163, Portland, Ore 97216), which is comparable to Mira-2-Tone®, could excellently stain the lesions and then could be easily distinguished from normal gingiva.

Several experimental and clinical studies support the assumption that excessive brushing force is partly responsible for the origin of toothbrush trauma (Arnim & Blackburn 1961, Alexander et al. 1977, Niemi et al. 1987). The average force with the D9 in the present study was 169 g. There seems to be a specific trend that the average brushing force for powered brushing is significantly less than the force usually used by manual brushing (Niemi et al. 1986, 1987, Phaneuf et al. 1962, Van der Weijden et al. 1996). In the present study no correlations could be found between force and abrasion. This indicates that other factors (e.g., brushing itself, tooth anatomy, bristle form) appear to be more important than the force used with an electric brush.

The present investigation showed that both electric toothbrushes and manual brushes cause minor gingival abrasion as a result of the brushing. In a study by Niemi et al. (1986, 1987), less gingival abrasion of the gingiva was found when an electric toothbrush was used compared to a manual brush. Walsh et al. (1989) found no differences between electric and manual toothbrushes with respect to gingival abrasion of the soft tissues. In their study however, subjects brushed at home. Therefore the brushing time, the brushing pressure and the brushing method may have differed. In agreement with Walsh (1989), the results of the present supervised brushing study showed no differences in the amount of gingival abrasion caused by either the electric or manual brushes using standardized brushing time and procedures. Given the model we have used, and the fact that we gave only a brief oral hygiene instruction, we did not expect a difference in efficacy between the D9 and the manual toothbrush. However it suited the purpose of the present study better to have equal efficacy comparing gingival desquamation scores for both brushes.

In a previous study by Van der Weijden et al. (1996) it was observed that different brushing forces were used with different electrical toothbrushes. One possible explanation for this finding could be the brushhead speed. The hypothesis was: the individual perception of speed could be responsible for a feedback effect, causing different forces when using different brushes with different motion frequencies. The results of the present study show that this is not the case with this oscillating rotating motion.

Breitenmoser et al. (1979) evaluated the effect of bristle end form on the gingival surface. They found that manual toothbrushes with cut bristle ends resulted in significantly greater gingival lesions than rounded ends using an average brushing force of 500 g. The round bristle ends appeared to be less abrasive than the cut bristle ends. Both bristle types used in the present study had different styles of endrounding (Fig. 1). The "roman"-shaped endrounding and the "gothic"-shaped endrounding in the present study are endroundings that can be produced. For the toothbrushing exercise in this study a new brushhead was used every time. This implies that for the experiment a maximum possible abrasive effect was scored. However one may question whether these types of endrounding will remain when the brush is used daily. The results of a study by Kreifeldt et al. (1980) suggest that usage of a brush will change the original endrounding due to wear. They observed that bristles of used toothbrushes in many instances show a tapering, proceeding from the insertion to the free end. When in the present study, the number of sites of abrasion are compared before and after brushing, significantly more small spots of gingival abrasion were found after panellist brushing than before. The gothic-shaped endrounding resulted in more small sites of gingival abrasion than the roman-shaped endrounding. The incidence of sites of abrasion post-brushing was larger in the first part (manual and electric brush) of the study than in the second (2 electric brushes). However the pre-brushing scores in both parts were comparable. This indicates that the participants are probably important for the observed effect. These results show that within this study model it is necessary to add a control such as a manual toothbrush or another brush of which the effect compared to the manual brush is known. For both the manual versus electric comparison and the 2 different types of endrounding no relationship between efficacy and the incidence of gingival abrasion was observed. This indicates that effective brushes are not more prone to gingival abrasion.

**In conclusion**

Toothbrushing has been shown to cause gingival abrasion. Endrounding has no effect on efficacy but does affect the incidence of gingival abrasion. The incidence of gingival abrasion is comparable between the manual and the electric toothbrush and is not influenced by brushing force.

**Zusammenfassung**

Beurteilung der beim Zähneputzen vorkommenden gängigen Abrasionsstiden

Résumé

Evaluation de l’incidence de l’abrasion gingival sur le brosse à dents dentaire

Les buts de l’étude présentaient étaient (1) d’établir l’incidence de l’apparition de l’abrasion gingivale comme résultat du brosse à dents dentaire en utilisant une brosse manuelle et électrique, (2) d’établir l’influence de l’extrémité arrondie du poil de la brosse à dents sur l’incidence de l’abrasion gingivale et l’efficacité du brosse, (3) d’établir si la vitesse de la brosse électrique avait un effet feedback sur la force de brossage utilisée et de mettre en corrélation l’incidence de l’abrasion gingivale avec la force. Deux expériences ont été menées. Dans la première expérience, 50 sujets se sont brossé durant 3 semaines tous les deux jours

avec une brosse à dents manuelle (Butler 411) ou électrique (Braun/Oral-B Ultra Plaque Remover-D9). Tous avaient reçu des courtes instructions et toute forme d’hygiène bucale a été arrêtée vingt-quatre heures avant leur rendez-vous. Après avoir coloré les dents et les gencives avec une solution Mira-2-Tone, la plaque dentaire et l’abrasion gingivale ont été mesurées. Ensuite les patients se sont brossés par bourse divisée au hasard. Après brossage et une deuxième coloration, la quantité de plaque dentaire et le grade d’abrasion ont été réévaluées. Les résultats ont montré que l’incidence de l’abrasion gingivale était comparable pour la brosse manuelle et électrique. En utilisant un modèle semblable à celui utilisé pour l’incidence de l’emmelage, la plaque carieuse et le grade d’abrasion des dents ont été mesurées. Immédiatement après ce brossage les sujets se sont brossés avec la brosse D7 (2800 rpm) et la D9 (3600 rpm) et la force de brossage a été mesurée. Les résultats de cette expérience ont montré que l’extrémité arrondie n’avait pas d’effet sur la plaque carieuse mais qu’elle avait une influence sur l’abrasion gingivale. La force de brossage n’était pas influencée par la vitesse de la tête de brossage et n’était pas en relation avec l’incidence de l’abrasion gingivale. L’abrasion gingivale n’est donc pas influen- cée par la force de brossage mais bien par l’extrémité arrondie du poil de la brosse.

References


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