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High and low brushing force in relation to efficacy and gingival abrasion

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Abstract

Objectives: Does a high brushing force induce more gingival abrasion than a low (regular) brushing force? Furthermore, what is the effect of a low or high force on the efficacy?

Methods: Thirty-five non-dental students were selected. All received an appointment prior to which they abstained from oral hygiene for at least 48 h. At baseline the teeth and surrounding tissues were disclosed using Mira-2-Tone® disclosing solution. Next, the examiner (PAV) evaluated the number of sites with gingival abrasion and the amount of dental plaque (Quigley & Hein) at 6 surfaces of each tooth. In the absence of this examiner, the subject's teeth were brushed by a hygienist (MP) using the Braun/Oral-B®-D17 oscillating rotating toothbrush. Brushing was performed in two randomly selected contra-lateral quadrants for 60 s with either a low force (± 1.5 N) or high force (± 3.5 N) and in the opposing quadrants for 60 s with the alternative force. Visual feedback was given to control force. The brush was moved from the distal tooth to the central incisor perpendicular to the tooth surface with an angle of approximately 10–15° towards the gingival margin. Next, the number of sites with abrasion and the remaining plaque were assessed again.

Results: The overall baseline gingival abrasion scores were 3.1 and 3.2 sites for high and low force, respectively, and increased to 5.0 and 5.9 sites respectively after brushing. There was no significant difference with respect to incidence of abrasion. At baseline, 48 h. plaque levels were 2.2. The reduction in plaque scores with the low force was 60% and with the high force 56%. This difference was significant.

Conclusion: With the oscillating rotating power toothbrush (Braun/Oral-B D17) the use of high force (± 3.5 N) is less efficacious as compared to a regular low force (± 1.5 N) while the incidence of gingival abrasion sites was comparable. (This study was sponsored by Gillette.)

Key words: gingival abrasion; oral hygiene; powered toothbrushes; toothbrushing force

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As a result of toothbrushing some people may traumatize the gingival tissues, which can in time lead to gingival recession. Abbas et al. (1990) showed that mechanical oral hygiene basically is a traumatic procedure. They observed increased bleeding upon probing scores shortly after oral hygiene procedures. Several experimental and clinical studies support the assumption that excessive force in brushing is partly responsible for the origin of toothbrush trauma (Arnim & Blackburn 1961, Alexander et al. 1977, Niemi et al. 1987).

Since 1960, a continuous development of different electric toothbrushes has evolved. 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 reviews: Hancock 1996, Saxer & Yankell 1997, Walmsley 1997, Sicilia et al. 2002, Weyant 2003).

The results from previous studies have shown the brushing force with powered toothbrushes to be lower as compared to a manual toothbrush (Van der Weijden et al. 1996). This appears to be a consistent finding: there is an approximately 1.0 N difference between the manual and the powered toothbrushes.

Recently, McCracken et al. (2003) observed, in a range 0.75–3.0 N, that the improvement in plaque removal, using a power toothbrush with forces in excess of 1.5 N was negligible. In a feedback study a professional brusher was asked to brush at 1.0, 1.5, 2.0, 2.5 and 3.0 N during which the efficacy in relation to brushing force to brushing was determined. An increase in efficacy was observed with raising brushing force from 1.0 to 3.0 N. The relationship between force and efficacy appears not to be linear, as shown in a manual brushing study in which efficacy was plotted against brushing force (Van der Weijden et al. 1998). Using this particular manual toothbrush a positive correlation between efficacy and force up to 4.0 N was found. The more force was used, the more effective the brushing. However, efficacy was reduced above 4.0 N, and there appeared a negative correlation. The hypothesis was that this had to do with distortion of the brushing filaments (Uenoyama & Inada 1990). Above 4.0 N the brushing was no longer performed with the tip of the filament, but, due to bending, with its side.

Little information regarding gingival abrasion due to toothbrushing with an electric toothbrush appears to be present (Danser et al. 1998b). From what is known it appears that electric toothbrushes are at least as safe as a manual toothbrush. In response to patients who use excessive force, manual and electric toothbrush manufacturers have introduced toothbrush designs, which can limit the amount of force used and thus reduce the chance of damage to soft and hard tissues (e.g. Soparker et al. 1991, Van der Weijden et al. 1995).

The aim of this research project was to evaluate the amount of gingival abrasion when using a constant high brushing force ($\pm$ 3.5 N), compared to a constant lower (regular) brushing force ($\pm$ 1.5 N) and furthermore, to assess the effect of these forces on plaque-removing efficacy.

Material and Methods

Subjects

A total of 35 healthy non-dental students, nine male and 28 female with a mean age of 23.9 years (range 18–42) participated in the study. All subjects eligible for the study were given oral and written information about the products and purpose of the study. Before entering the study, they gave written informed consent.

Selection was based on the inclusion criteria:

- At least five evaluable teeth in each quadrant.

The exclusion criteria for subjects were:

- Presence of a removable prosthesis.
- Orthodontic banding or retention wires.
- Oral lesions or periodontal problems (sites with PPD $\geqslant$5 mm).
- History of periodontal disease.
- Presence of acute intraoral lesions.

Toothbrush

The Braun Oral-B 3D EXCEL Plaque Remover (D17) (Braun AG, Kronberg, Germany) makes a rotary back and forth movement at a speed of 3600 oscillating/rotations per minute (60 Hz) with an angle of 60°. It has an additional pulsating brush head action in the direction of the long axis of the bristle filaments. At a brushing force levels over 2.5 N this pulsating action discontinues. The brush head used was a regular Oral-B brush head, the EB17. The brush was equipped with a visual force indicator, which could be set at two force ranges: 1.5 ± 0.5 and 3.5 ± 0.5 N. The brush was online with a com puter, which registered and recorded the brushing force used by the professional brusher (MP) at a sample rate of 15 Hz. Before each brushing exercise, the force sensor was calibrated. Two toothbrush handles were available which were used alternately to ensure that the battery was always fully charged.

Professional brushing

All participants were stained for plaque and received a thorough supragingival scale and polish to remove all plaque, stain and calculus. This professional prophylaxis was given by a dental hygienist and the teeth were polished, so that all subjects started with a plaque-free dentition.

Subjects were then asked to abstain from all oral hygiene procedures for 48 h to allow plaque to accumulate for the professional toothbrushing episode. At this visit both the gums and teeth were disclosed by Mira-2-Tone® disclosing solution (Hager & Werken, GMBH & Co., Duisburg, Germany). Mira-2-Tone® solution was used for better visualization of areas where the surface of the oral epithelium has been abraded (Breitenmoser et al. 1979, Danser et al. 1998a). A complete oral soft tissue examination was performed. The number and site location of the gingival abrasions were then recorded on the case record form (CRF). The gingival tissues were divided into three areas: marginal (marginal free gingiva), interdental (papillary-free gingiva) and mid-gingival (attached gingiva). In the upper jaw the palatal mid-gingival area comprised the whole hard palate. The abrasions were measured by using a Williams periodontal probe placed across the long axis of the lesions. Gingival abrasion present on the tooth-related soft tissues was assessed and recorded using the method adapted from Danser et al. (1998a). The abrasions were scored as:

- small, if Ø$\leqslant$2 mm,
- medium, if Ø$\geqslant$3, but $\leqslant$5 mm,
- large, if Ø$>$5 mm.

Those lesions measuring 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 according to the Quigley & Hein index (1962) at six sites per tooth (Lobene et al. 1982 and Turesky et al. 1970 modification). All teeth were scored, with exception of central incisors and third molars.

Next, the participants were brushed by a dental hygienist for 60 s using the D17 with their first assigned target brushing force (being either 1.5 or 3.5 N) in two randomly selected contra-lateral quadrants. Brushing was repeated (another 60 s) with the alternative force in the opposing two contra-lateral quadrants. Thus, brushing time for the whole mouth was 2 min. Visual feedback was given to the professional brusher indicating when the brushing force was within the preset range. For each target force range new brush heads were used so that the change of bristle stiffness during use as a result of humidity and wear in one force range would not affect the stiffness in the other range. All toothbrushing took place in a separate room from the examiner to retain blindness of the study. After a second disclosing with Mira-2-Tone®, remaining plaque and the visible gingival abrasions were assessed.

Examiner

All clinical examinations were performed by the same examiner (PAV) using the same dental unit and operating lamp. At the time of examinations the examiner was unaware of the brushing force. 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.

Data analysis

Full mouth mean scores for plaque were calculated. Scores were calculated for regions of interest and different tooth types. Trauma scores were calculated as the total number of sites with abrasion and separately as the number of small, medium and large sites. The plaque scores after brushing were used as the main response variable. A repeated measures analysis with baseline plaque scores as a co-variate was performed, with subsequent residuals analysis. Further explorative analysis was performed on regions of interest and different tooth types using a Wilcoxon test. All gingival abrasion analyses comparing differences between the 'high' and 'low' brushing force were performed using Wilcoxon tests. Two-sided values of $p \leqslant 0.05$ were accepted as statistically significant.

Table 1. Plaque scores and plaque reduction in terms of percentage for low and high force; full-mouth indices and indices for different tooth types

	Low force	High force	*p*-Value*
All sites			
base plaque	2.24 (0.33)	2.23 (0.35)	
end plaque	0.89 (0.32)	0.97 (0.34)	
diff plaque	1.35 (0.35)	1.26 (0.37)	
%red plaque	60% (13)	56% (14)	0.0241
Front			
%red plaque	69% (15)	64% (17)	0.0897
Premolars			
%red plaque	60% (18)	53% (17)	0.0142
Molars			
%red plaque	52% (14)	52% (16)	0.8504

Standard deviations in parentheses.
*Tested with Wilcoxon test.

Table 2. Plaque reduction in terms of percentage for low and high force presented for different tooth surfaces

	Low force	High force	*p*-Value*
approximal vestibular	48% (14)	43% (14)	0.0227
mid-vestibular	81% (12)	75% (19)	0.0353
all vestibular	58% (12)	53% (13)	0.0106
approximal lingual	56% (23)	53% (23)	NS
mid-lingual	84% (14)	81% (17)	NS
all lingual	64% (19)	61% (19)	NS

Standard deviations in parentheses. NS, not significant.
*Tested with Wilcoxon test.

Table 3. Abrasion scores and mean brushing forces for low and high target forces presented as a summary and by different sizes of abrasion

Trauma	Target low force		Target high force		*p*-Value
	baseline	difference	baseline	difference	
total	3.1 (3.8)	5.0 (3.2)	3.2 (3.6)	5.9 (3.6)	0.25
small	2.6 (3.6)	4.3 (3.3)	2.8 (3.2)	5.2 (3.6)	0.35
medium	0.3 (0.5)	0.7 (0.9)	0.4 (0.9)	0.6 (1.2)	0.77
large	0.1 (0.4)	0.0 (0.4)	0.1 (0.3)	0.2 (0.4)	0.06

Results

The overall results of this study are presented in Table 1. The plaque reduction in terms of percentage with the low force (1.5 N) was 60% and 56% with the high force (3.5 N). The low force was significantly more effective than the high force.

Explorative testing of the data which are presented in Tables 1 and 2 indicate that the significant difference, which is observed between low and high force probably is a result of decreased efficacy at the premolars and the vestibular surface with the high force. The significant differences between the efficacies of the two forces at these specific sites ranged from 5% to 7% plaque reduction.

The increase in overall abrasion scores (total) was 5.0 sites after 2 min of brushing with the low force (Table 3). An increment of 5.9 sites was observed with the high force. There was no statistically significant difference between the two brushing forces with regard to gingival abrasion. Mainly responsible for the increase in the number of abrasions are small sites with a mean increment of 4.3 sites with the low force and 5.2 with the high force. Fig. 1 shows the abrasion data as presented by area of interest. With both high and low brushing forces most abrasion is obviously found at the mid-gingival aspect. The abrasion data show no difference between both brushing forces.

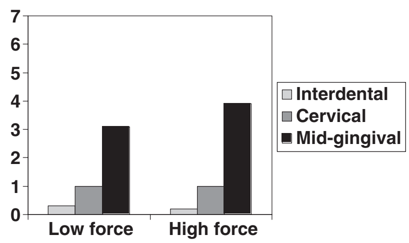

Fig. 1. Mean number of small abrasion sites presented by area of interest.

The target low force was intended to be on average 1.5 N. It was recorded with an overall mean of 1.6 ($\pm$ 0.1) N and a frequency of 93% ($\pm$ 4) of the professional brusher to be in the given range of 1–2 N. The mean target high force was on average 3.5 ($\pm$ 0.1) N as intended with 81% ($\pm$ 5) of the brushing time being within the given range of

3–4 N. The significant difference in frequency indicates that it is easier to maintain the low brushing force ($p<0.00005$).

Discussion

The present study was designed to evaluate the effect of brushing force on brushing efficacy and gingival abrasion. It used two preset force ranges in a controlled professional brushing study. It also evaluated the forces that were actually used in this design. Interestingly, the present study showed that with the higher mean force, less efficacy is obtained as compared to the lower force.

Recently, McCracken et al. (2003) observed in a range from 0.75 to 3.0 N that the improvement in plaque removal using a power toothbrush with forces in excess of 1.5 N was negligible. This appears to be in contrast with the previous work which indicated that with increase in force an increase in efficacy is reached (Hasegawa et al. 1992, Van der Weijden et al. 1998). However, as stated in the introduction, the previous work (Van der Weijden et al. 1998) has shown that with increasing force the efficacy increased up till a certain point after which a negative correlation was observed. Possibly each individual brush has its own efficacy profile in relation to the force used.

Another explanation for the lower efficacy with the high force could be found in the difficulty it has taken the professional brushing to brush close to the target force. With the low target force, 93% of the time this was within the range, whereas with the high force, it was 81% of the time. It is conceivable that more attention was needed with the high force, which in the mean time could not be spent on the brushing procedure and technique. Apart from these possible explanations for the finding of a lower efficacy at the high force level, one has to keep in mind that the high force level exceeds the force at which the pulsating motion of the brush head in the direction of the bristles discontinues (2.5 N). Therefore, at the high force only the oscillating rotating movement is active. This may also influence the plaque-removing efficacy.

Gingival abrasion is difficult to score since visible gingival abrasion is not a common finding. For the present study, the method as first described by Breitenmoser et al. (1979) was chosen, in which the lesions are stained so that they are easily distinguishable from normal gingiva (Danser et al. 1998a). This method has been further refined by assessing abrasion on the interdental, cervical and mid-gingival aspects of the gingival, as well as taking the size of the lesion into account by differentiating between small and large abrasions. In previous studies, abrasion sites were scored as small and large sites. For the purpose of the present study the lesions with $\varnothing \leqslant 5$ were further defined as small ($\varnothing$ 1–2 mm) and medium ($\varnothing$ 3–5 mm) abrasions. The presence and incidence of medium ($2\,\text{mm} < \varnothing < 5\,\text{mm}$) and large ($\varnothing > 5\,\text{mm}$) sites of abrasion appears to be an uncommon finding. The present data corroborate the observation of previous studies (Danser et al. 1998a, b, Van der Weijden et al. 2001), where the largest effect of brushing was found as an increase of smaller lesions ($\varnothing \leqslant 5\,\text{mm}$). The present data suggest that these previous findings are most probably due to the increase in number of true 'small' lesions of 1–2 mm. Therefore, small sites (1–2 mm) appear to be more of interest when considering the incidence of abrasion as a result of brushing. The data show that with low force the increase in sites with abrasion was approximately five sites and with high force 6 sites. This was not a significant difference. This is in agreement with the results of Danser et al. (1998a) who found no correlation between brushing force and gingival abrasion. Mierau et al (1989) performed a quantitative assessment of habit patterns of toothbrushing in 28 subjects and nine sessions. Least variations within each individual were observed with regard to brushing force. Brushing force ranged from 1.0 to 7.4 N between individuals. They did not observe any (visual) brushing lesions in those individuals that had a brushing force $\leqslant 2$ N. If the brushing force was >2 N co-factors such as brushing time, brushing method and frequency of brushing appeared to be associated with respect to acute brushing lesions. These studies indicate that other factors than brushing force may be more important.

In conclusion, the present study has shown given a range of brushing force of approximately 1 N the professional brusher was able to brush on average at the set target brushing force. With the oscillating/rotating toothbrush (D17), the use of high force ($\pm$ 3.5 N) is less efficacious as compared to a low (regular) force ($\pm$ 1.5 N) while the incidence of gingival abrasion sites was not different between both forces.

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