

# Plaque removal by worn toothbrush

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## Abstract

**Background/aims:** Assessment of the influence of toothbrush wear on plaque (PI) and gingival (GI) indexes.

**Method:** 20 university students were recruited. PI and GI were recorded at the starting point (T0). Each subject received a toothbrush and toothpaste. 5 measurements of toothbrush were recorded to establish the initial size. The subjects were instructed to brush 3× a day and to refrain from using other plaque removal aids. After 1 month (T1), the subjects were randomly divided into 2 groups: group no. 1 substituted the toothbrush at each monthly visit; group no. 2 brushed only with the toothbrush provided at T0. Recalls were scheduled after 1 (T1), 2 (T2) and 3 months (T3). PI, GI and an index of wear (WI) were calculated using 5 measurements of the toothbrush head and were recorded at recalls.

**Results:** From T0 to T3, a significant increase of PI was found within both groups. Non-significant differences, but very close to the significant level ( $p=0.063$ ), in group no. 1 and significant differences in group no. 2 of GI were found. No significant differences of PI and GI were found between groups. Increase of the WI was registered from T0 to T3 ( $p<0.001$ ).

**Conclusion:** Each individual is capable of maintaining low PI, even if using a toothbrush that shows evidence of wear.

Key words: oral hygiene; toothbrush; toothbrush wear; dental plaque, plaque control

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Until now, only a limited number of clinical trials have investigated how toothbrush wear affects plaque removal (McKendrick 1971, Bergstrom 1973, Kreifeldt et al. 1980, Glaze & Wade 1986, Dean et al. 1992, Daly et al. 1996). On the other hand, many clinical trials have been engaged in research to justify the efficiency of plaque removal using different types of toothbrushes, both manual and powered (Charters 1948, Bass 1954, Scully et al. 1970, Scoop et al. 1976, Bastiann 1986, Glavind & Zeuner 1986, Shory et al. 1987, Ciancio 1989, Yankell et al. 1992, Sharma et al. 1992, Singh et al. 1992, Battista et al. 1993, Balanyk et al. 1993, Deasy et al. 1993, Johnson & Mc Innes 1994, Claydon & Addy 1996, Tritten et al. 1996).

One of the reasons that few studies are available in literature may be attributed to the difficulty in achieving a standard and objective method for evaluating toothbrush wear (Kreifeldt

et al. 1980). According to patients (Dean 1991, Dean et al. 1992, McKendrick et al. 1971) and dental operators (Glaze & Walde 1986, Kreifeldt et al. 1980, Massassati & Frank 1982, Abraham et al. 1990), the spreading and bending of toothbrush bristles are the main indicators of wear. These are the signs for toothbrush replacement.

Some authors showed a correlation between the life of a toothbrush and plaque removal efficiency (Dean 1991). In contrast, other authors did not find any correlation between the life span of a toothbrush and the results of periodontal and oral debris indexes (Mc Kendrick et al. 1971, Abraham et al. 1990, Dean et al. 1992). In any case, all the authors suggested that the average replacement time of a toothbrush ranges from between 2.5 and 6 months. (Mc Kendrick et al. 1971, Abraham et al. 1990, Dean 1991, Dean et al. 1992).

The study conducted by McKendrick et al. (1971) suggests that, in order to

determine toothbrush wear, brushing technique may be more important than the length of time of use of a toothbrush. The relation between toothbrush wear and plaque removal was investigated by Kreifeldt et al. (1980), Glaze & Wade (1986) and recently by Daly et al. (1996). Kreifeldt et al. (1980) observed that the grade of toothbrush wear, created artificially, is responsible for a parallel reduction in the efficiency of plaque removal. In a 10-week study, Glaze & Wade (1986) reported an increase in the values of the plaque and gingival indexes in patients who used the same toothbrush for the duration of the study, compared with the values of those who replaced the toothbrush every 2 weeks. In contrast, Daly (1996) in a 9-week study on 20 patients, showed a decrease in the plaque index unrelated to toothbrush wear. The results of the above mentioned studies are not homogeneous. Consequently, the correlation between toothbrush wear

Table 1. Plan of the experiment

T - 2	T - 1	T0	T1	T2	T3
45 days before T0 1st visit and patients selection	1 month before T0 professional oral hygiene and motivation	time 0 toothbrush is issued; start of the experiment PI and GI recorded	1 month later; random distribution of the subjects into 2 groups • group no. 1: toothbrush collection and measurements; PI and GI recorded used toothbrush of group no. 1 was replaced with a new one • group no. 2: PI and GI recorded; measurements of the toothbrush	2 months later • group no. 1: toothbrush collection and measurements; PI and GI recorded; used toothbrush was replaced with a new one • group no. 2: PI and GI recorded; measurements of the toothbrush	3 months later collection and measurement of all the toothbrushes; PI and GI recorded in all subjects

and its ability in plaque removal has not been definitively determined.

The purpose of this 3-month study was to verify the impact of the progressive wear of the toothbrush on plaque control.

**Material and Methods**

University students of non-medical faculties were recruited for a 3-month, double-blind study. The inclusion criteria used were: (a) the patients were healthy and did not consume any medication that could impair their usual level of oral hygiene; (b) patients had at least one molar, one premolar and one incisor in each quadrant. In order to participate, the patients signed a witnessed consent form and committed themselves not to undergo dental treatment during the three month period of the study.

For each patient, 12 teeth were selected. One incisor, one premolar and one molar in each quadrant. The selected teeth were required to be caries free, without restorations on the buccal or lingual-palatal surface and to exhibit a probing depth ≤3 mm. Table 1 illustrates the plan of the experiment. At T-2, 45 days before the start of the experiment (T0), a first visit was made. All the first visits were conducted by the same operator (Sf) to make a preliminary selection of patients. A total of 20 subjects (6 male and 14 female, age 20–32 years) were selected. At T-1, 1 month prior to the start of the experiment, all patients underwent an oral prophylaxis by a dental hygienist (Ca) and home care instructions were reinforced in order to obtain an adequate level of oral hygiene (medium plaque index score=

1.05). At T0, the same operator (Sf) who had selected the patients at T-2 evaluated 4 sites of each selected tooth (mesial, distal, buccal, lingual or palatal) in each patient. In each site, gingival index (GI) according to Løe & Silness (1963) was recorded. The surfaces were then disclosed with 10% erithrosine solution and a plaque index (PI) (Sillness & Løe 1964) was recorded.

Each participant received a toothbrush (Oral-B Plus 35 – Oral B Laboratories, Ireland) and toothpaste of low abrasiveness (Oral-B teeth and gums – Oral B Laboratories, Ireland). The toothbrush is designed with 4 rows of

bristles with a total of 39 tufts; 44 monofilaments per tuft. The height of the monofilament is 11.1 mm, the diameter of the monofilament is 0.20 mm.

Before issuing the toothbrush, an operator unrelated to the research, measured each one. In order to insure the accuracy of the procedure, the head of the toothbrush was anchored in a vice, illuminated by a constant light (halogen 150 W) and measured with a caliper with an accuracy of measurement up to a tenth of a millimeter under a 4.2 magnification using an optical stereomicroscope. According to Rawls et al. (1989), 5 measurements were recorded for each

Table 2. Plaque index

	Group no. 1 (changing toothbrush)		Group no. 2 (not changing toothbrush)		p-value
	M	(SD)	M	(SD)	
T0	0.020	(0.249)*	0.016	(0.206)*	0.701
T1	0.336	(0.257)*	0.251	(0.290)*	0.498
T2	0.243	(0.237)*	0.541	(0.384)*	0.054
T3	0.356	(0.325)*	0.445	(0.216)*	0.482

M=mean; SD=standard deviation.

\* Friedman’s ANOVA exact test  $p < 0.001$  ( $p$  computed using Monte Carlo method).

Table 3. Gingival index

	Group no. 1 (changing toothbrush)		Group no. 2 (not changing toothbrush)		p-value
	M	(SD)	M	(SD)	
T0	0.058	(0.547)	0.028	(0.420)*	0.192
T1	0.210	(0.208)	0.263	(0.371)*	0.698
T2	0.328	(0.316)	0.741	(0.558)*	0.057
T3	0.551	(0.452)	0.717	(0.385)*	0.389

M=mean; SD=standard deviation.

\* Friedman’s ANOVA exact test  $p < 0.001$  ( $p$  computed with Monte Carlo method).

Friedman’s ANOVA exact test  $p < 0.063$  not significant in group no. 1.

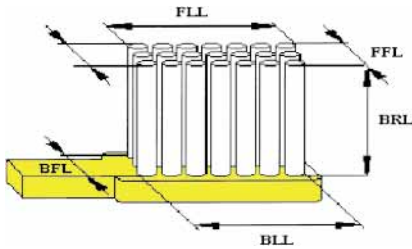


Fig 1. Toothbrush dimension measurements. BLL=lateral length at base; FLL=free lateral length; BFL=frontal length at base; FFL=free frontal length; BRL=bristles' length.

toothbrush (Fig. 1). FLL (free-long-length) is the maximum length of the brush measured on the longer side (non-anchored) of the head; BLL (base-long-length) is the maximum length of the brush measured on the longer side of the anchored end; FFL (front free length) is the maximum length measured in correspondence of the shorter side of the non-anchored end of the bristles; BFL (base free length) is the length of the shorter side measured on the anchored end.

The students were instructed to brush 3× a day using only the toothbrush and toothpaste that were given using a modified Bass technique (Bass 1954), and to refrain from using dental floss, mouthwashes or any other plaque removal aids. At T1, the subjects, without their knowledge, were divided into two groups with a block randomization procedure. Group no. 1 (3 male, 7 female) utilized the toothbrush received at T0 for just one month. After that, the toothbrush was substituted with a new one at each monthly visit. In contrast, group no. 2 patients (3 male, 7 female) were instructed to brush for the

whole period of the study with the toothbrush initially provided.

All subjects were blindly clinically evaluated at 1 month (T1), 2 month (T2) and 3 month (T3) intervals after the consignment of the toothbrush, by the same expert operator (Sf). PI and GI were recorded. Instructions about oral hygiene procedures were reinforced at each monthly examination by the dental hygienist (Ca).

All toothbrushes were measured by the operator unrelated to the research at T1, T2 and T3 and the Index of Wear (WI) was calculated according to the formula as suggested by Rawls et al. (1989):

$$WI = \frac{FLL - BLL + FFL - BFL}{BRL}$$

The PI and GI values that were recorded at each clinical evaluation at T0, T1, T2, and T3 were statistically analyzed within the groups with Friedman's ANOVA exact test using Monte Carlo method to compute probability.

Data from the group no. 1 were compared with that of the group no. 2 applying the Student *t*-test after checking the equality of variance using the Levene test. A linear regression analysis was utilized to show the correlation between the wear index and the plaque index. For this analysis, group no. 1 and group no. 2 data sets at T1 were used. The validity level was fixed at  $p \leq 0.05$ .

## Results

At baseline (T0) PI and GI values did not exhibit any statistically significant difference (Student *t*-test) between group no. 1 and group no. 2. Therefore, the groups were considered homogeneous at the start of the experiment.

Table 4. Index of wear in group no. 2 maintaining toothbrush

	Index of wear	
	M	(SD)
T0	0.015	(0.02)*
T1	0.273	(0.221)*
T2	0.384	(0.254)*
T3	0.516	(0.319)*

M=mean; SD=standard deviation.

\* Friedman's ANOVA exact test  $p \leq 0.001$  ( $p$  computed with Monte Carlo method).

Tables 2, 3 show that the mean value of the PI and GI both of group no. 1 and group no. 2 at T3 were slightly higher than that at T0. The significant increase of PI values from T0 to T3 in both groups were probably due to very low starting values of PI. Significant difference of GI was observed in group no. 2 while in group no. 1 the GI values showed a non-significant increase even if  $p$  value was very close to the significance level ( $p=0.063$ ). At T1 and T3, no statistically significant difference was shown between the groups. At T2 the difference of both PI and GI values between the two groups is not significant even if the values were very close to the significance level ( $p \leq 0.057$  and  $p < 0.054$  respectively). Regarding toothbrush wear, an increase of the WI value was registered from T0 to T3 in group no. 2 who had not changed the toothbrush ( $p \leq 0.001$ ) (Table 4). Nevertheless, the linear regression analysis did not show any significant correlation between WI and PI. Various entanglement styles and opaqueness of the bristles were observed (Fig. 2). WI means recorded after 1 month of use at T1, T2 and T3 were respectively 0.21, 0.24, 0.27.

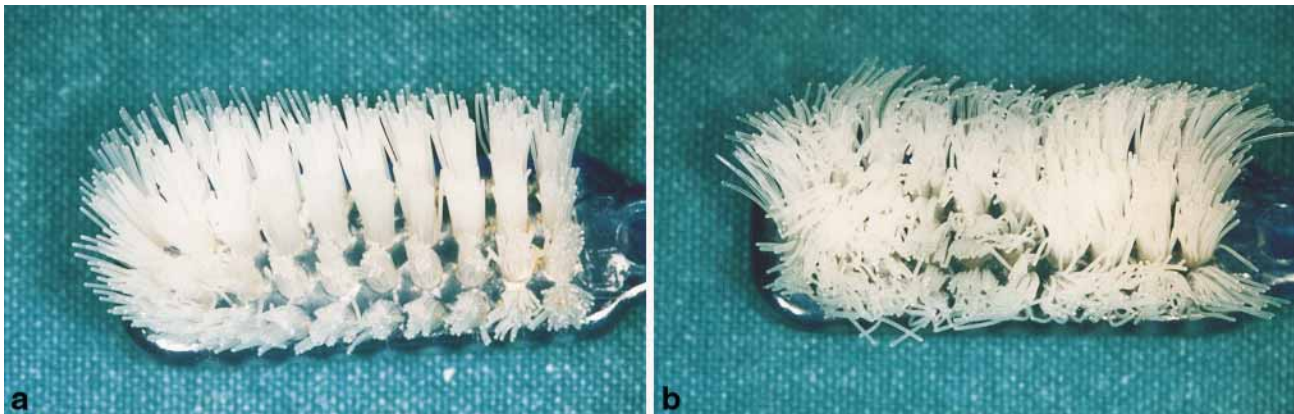


Fig. 2. (a) Toothbrush wear appearance after 1 month in group no. 1. (b) Toothbrush wear appearance after 3 months in group no. 2.

## Discussion

The results obtained from this 3-month clinical study suggested, within the limits of the present research, that the capacity to remove plaque is not related to toothbrush wear. A statistical analysis was used to compare the toothbrush wear index, plaque index and gingival index values in subjects who monthly substituted or, conversely, did not substitute their toothbrush; the analysis showed that there is not a significant difference in the comparison, with the exception of PI and GI values between the two groups at T2 which had a significance very close to the validity level. These results are in accordance with Daly et al. (1996) who reported that the efficiency of plaque control is not necessarily correlated to toothbrush wear.

Earlier studies (Glaze & Wade 1986, Kreifeldt et al. 1980) demonstrated that worn toothbrushes have less capacity to remove plaque compared with those less worn. The differences in the results of these mentioned studies may be related to variables such as: length of time employed in brushing, the type of toothbrush and the method applied to determine and calculate toothbrush wear. In particular, Glaze & Wade (1986) assessed less efficiency in plaque removal in subjects who had used the same toothbrush for a 10-week period versus subjects who replaced the toothbrush every two weeks. It may not be excluded that the efficiency of toothbrush in plaque removal may be maximum in the first 2 weeks and then it may fall in the following weeks.

Kreifeldt et al. (1980) conducted an investigation to prove the efficiency of toothbrushing on plaque removal using artificially worn toothbrushes. They evaluated the removal of bacterial plaque by measuring plaque and gingival indexes during brushing time, at settled intervals of 32.5 s for a total time of 130 s. Analogously to other studies (Glaze & Wade 1986, Daly et al. 1996), Kreifeldt et al. (1980) refrained from giving instructions regarding a specific length of time in brushing; instructions were only given as to which brushing technique to use and to brushing frequency. Therefore, it may be supposed that the patients correctly brushed their teeth for longer than usual lengths of time and with such an efficiency that these 2 factors counterbalanced every potential decrease in plaque removal efficacy imputable to progressive tooth-

brush wear. In any case, different degrees of toothbrush wear, mechanically attained, are relevant to different grades of plaque removal.

However, we assume that the use of artificially worn toothbrushes may not be considered an objective method to evaluate the efficacy of plaque removal since it only approximates the characteristics of naturally worn toothbrushes. As a matter of fact, even if artificially obtained splaying and opacity of the bristles closely resemble the characteristics of naturally worn bristles, other factors may influence and modify the intrinsic characteristics of the bristles, such as: the rubbing against the tooth surface, its interaction with food particles and bacterial plaque, abrasiveness characteristics of toothpastes and natural aging of the bristles.

In the study by Glaze & Wade (1986) measurements of toothbrush wear were determined in 2 ways: (a) toothbrushes were individually measured and categorized in one of the three groups constituted according to a criterion of progressive wear; (b) toothbrushes were evaluated measuring the increase of the area of the brushing surface using a caliper with an accuracy up to 0.1 mm.

The 2nd method may be criticized because the area of the brushing surface was calculated multiplying only the higher measurement of length by the higher of width; since the brushing surface of worn toothbrushes is usually irregular toward the outer section, it is possible to ascertain only an approximate calculation of the area of the brushing surface and therefore of toothbrush wear. For this reason, the criteria that were used to measure toothbrush wear in our study is based on a mathematical formula proposed by Rawls et al. (1989) that doesn't relate to brushing surface, but takes into consideration 5 different measures of length (FLL, BLL, FFL, BFL, BRL). This calculation leads to a more generalized comparative evaluation of the deformation of the bristles that is directly related to toothbrush wear. For this reason the original formula has been suggested to set standards for quality control of the toothbrushes (Rawls et al. 1989). Some experimental research (Lentz et al. 1991) has demonstrated that toothpastes with a high grade of abrasiveness consume the bristles of the toothbrush more evidently than when a gel toothpaste is used. For this reason, the patients in our study used a toothpaste of low abrasiveness,

therefore minimizing its effect on the wear of the bristles.

This observation has also been confirmed by previous studies (Bergström 1973, Dean et al. 1992, McKendrick et al. 1971, Bass 1954), and it may be supposed that this is due to the fact that the applied force of each individual while brushing is different (Fraleigh et al. 1967). The research conducted by Pugh (1978) revealed, in a group of individuals, mean forces of brushing ranging from 4 N to 20 N and a proportional relationship between force applied while brushing and toothbrush wear.

In our study, as in that of Daly (1996), there are no significant differences in the PI and the GI values of patients with greater or less toothbrush wear. This observation suggests that plaque control is not dependent only on the toothbrush wear and it is rational to suppose that other factors may be influential such as time or brushing pressure. Among the reasons that lead to our results, it may not be excluded that the patients had better plaque control because they were subjected to an accurate monthly control visit. On the other hand, it is important to note that the patients treated in this study, as opposed to Daly et al. (1996), were neither medical nor dental students. This allows less influence on the results because the subjects in our study presumably had not been so informed of the problems related to oral hygiene. Within the limits of our study, it is possible to conclude that each individual is capable of maintaining good oral hygiene with a low plaque index even if using a toothbrush that shows evidence of wear.

## Zusammenfassung

### *Plaquentfernung durch eine gebrauchte Zahnbürste*

Das Ziel der Studie war es den Einfluß der Abnutzung einer Zahnbürste auf den Plaque- (PI) und Gingiva-Index (GI) zu messen. Zwanzig Universitätsstudenten wurden rekrutiert. PI und GI wurden zu Studienbeginn (T0) erhoben. Jede Versuchsperson erhielt eine Zahnbürste und eine Zahnpasta. Fünf Messungen an der Zahnbürste wurden aufgezeichnet, um ihre initiale Dimension zu dokumentieren. Die Personen wurden dazu angeleitet, dass sie drei Mal am Tag putzen und keine anderen Hilfsmittel verwenden. Nach 1 Monat (T1) wurden die Personen randomisiert in zwei Gruppen aufgeteilt. Gruppe-1 ersetzte die Zahnbürste bei jedem monatlichen Termin. Gruppe-2 putzte nur mit der an T0 zur Verfügung gestellten Bürste. Die Recalls erfolgten nach einem (T1), 2 (T2) und

3 (T3) Monaten. Während der Recall-Sitzung wurden der PI, GI und der Abnutzung-Index (WI) aus den fünf Messungen am Bürstentkopf errechnet. In beiden Gruppen wurde von T0 bis zu T3 ein signifikanter Anstieg des PI vorgefunden. Keine signifikanten Unterschiede, jedoch nach am Signifikanz-Level liegen ( $p=0.063$ ) wurden in Gruppe-1 für den GI gefunden. Signifikante Unterschiede im GI gab es bei Gruppe-2. Zwischen den Gruppen wurden für den PI und GI keine signifikanten Unterschiede vorgefunden. Eine Zunahme des WI wurde von T0 zu T3 registriert ( $p<0.001$ ). Die Schlußfolgerung ist, dass jede Person einen niedrigen PI aufrecht erhalten kann, sogar wenn sie eine Zahnbürste benutzt, die Abnutzung aufweist.

## Résumé

### Elimination de plaque dentaire par brosse à dents usagée

Le but de cette étude a été d'analyser l'influence de l'usure de la brosse à dents sur l'indice de plaque (PI) et l'indice gingival (GI). 20 étudiants ont participé à cette étude. Les PI et GI ont été notés lors de l'examen initial (T0). Chaque sujet a reçu une brosse à dents ainsi que du dentifrice. 5 mesures de la brosse à dents ont été effectuées au niveau de sa tête afin d'en établir sa dimension. Des étudiants ont été instruits à se brosser les dents trois fois par jour, sans avoir recours à quel qu'autre méthode de contrôle de plaque. Après 1 mois (T1), 16 étudiants ont été répartis en 2 groupes. Le groupe 1 changeait brosse à dents à chacune des visites mensuelles. Le groupe 2 brossait uniquement avec la brosse à dents procurée au T0. Les rappels ont été effectués après 1 (T1), 2 (T2) et 3 mois (T3). PI et GI ont été mesurés lors de tous les rappels, de même que l'indice d'usure (WI), calculé à l'aide des cinq mesures de dimension de la tête de la brosse. De T0 à T3 une augmentation significative de PI a été trouvée dans les deux groupes. Aucune différence significative ( $p=0.063$ ) n'a été trouvée dans le groupe 1 par contre, des différences significatives ont été trouvées dans le groupe 2 pour le GI. Entre les groupes, aucune différence pour les PI et GI n'a été trouvée. Une augmentation de WI a été enregistrée entre T0 et T3 ( $p<0.001$ ). Chaque individu est donc capable de maintenir un PI bas malgré un niveau d'usure de sa brosse à dents.

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