Research

The Effect of Brushing Time and Dentifrice on Dental Plaque Removal *in vivo*

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Abstract

Purpose: Routine toothbrushing is the principal method by which individuals remove plaque and control plaque-related diseases, such as periodontitis and caries. Oral health care professionals generally recommend at least 2 minutes brushing with an appropriate technique, and yet the average brushing time in the general population is closer to 45 seconds. Our understanding of the relationship between brushing time and plaque removal, in an untutored general population using a conventional manual toothbrush and dentifrice, is limited. The role of dentifrice in plaque removal is also unclear.

Methods: This study was undertaken to measure plaque removal during untutored brushing over timed periods between 30 and 180 seconds with 1.5g dentifrice, using an Aquafresh Flex® brush and Aquafresh Advanced® dentifrice. Plaque removal after brushing without dentifrice was also determined (at the 60 second time point only). Forty-seven subjects participated in the study, in which plaque level was assessed using the Quigley-Hein (Turesky-modification) Index.

Results: Plaque removal increased with brushing time across the range studied, tending towards a maximum at longer brushing times. At the extremes, brushing for 180 seconds removed 55% more plaque than brushing for 30 seconds. Brushing for 120 seconds removed 26% more plaque than brushing for 45 seconds. The use of dentifrice did not increase plaque removal during 60 seconds of brushing.

Conclusions: Oral health care professionals should reinforce efforts to persuade patients to brush for longer periods of time, as increasing brushing time to the consensus minimum of 2 minutes from a more typical 45 seconds increases plaque removal to an extent likely to provide clinically significant oral health benefits.

Key Words: toothbrush, dentifrice, plaque, brushing, duration

Introduction

Routine toothbrushing is perhaps the single most important step an individual can take to reduce plaque accumulation and the consequent risk of plaque-associated diseases, such as periodontitis and caries.[1-9] Studies of the relationship between time spent brushing and oral hygiene have been inconsistent.[10-13] However, when the effect of brushing time on plaque removal has been studied on a within-subject basis, a significant effect on plaque removal has been observed.[14-19]

There have been several studies on the effects of plaque removal concerning the type of brush, brushing technique, and frequency of brushing.[20-25] However, the authors could find no existing study on the effects time spent brushing had on plaque removal in the general population – that is, when subjects are untutored in brushing technique and are not linked to the oral health profession. Yet this represents the most common situation, and brushing time is important to cleaning the teeth properly and the consequent oral health benefits. Brushing time is the most easily controlled parameter of effective everyday brushing.

The general consensus amongst oral health care professionals is that individuals should spend at least 2 minutes brushing their teeth with an effective technique at least twice a day, though specific recommendations from national dental associations are frequently lacking. However, most estimates of actual brushing time vary between just over 30 seconds to just over 60 seconds.[10,16,17,26-32] Some caution regarding these estimates should be exercised as the act of measuring brushing time has been shown to affect brushing behavior.[30] The recent study of Beals et al[33] determined an average of 46 seconds from a home-use study involving 173 U.S. adults. It is clear that the average time spent brushing is considerably shorter than 2 minutes, and a value of about 45 seconds would seem a useful estimate.

Therefore, the aim of this study was to determine whether brushing time is an important determinant of plaque removal during conventional toothbrushing. A sample representa-

tive of the general population using their normal brushing technique was tested. Differences in plaque removal could then be related to the possible impact on overall oral health. A specific objective was to compare the effect of brushing for 2 minutes with brushing for 45 seconds, representing a comparison of the plaque removal benefits of brushing for the consensus minimum time with brushing for the estimated average time. This should assist oral health professionals in encouraging their patients into a more effective oral hygiene routine.

Methodology

The study design consisted of a randomized, single-center, single-product, multi-use, 6-way crossover. This design allowed treatment comparisons on a within-subject basis, to maximize the ability to detect treatment differences. The plaque index used in this study was the Turesky modification[34] of the original index of Quigley and Hein,[35] as modified subsequently by Lobene et al[36] to include 6 sites per tooth (the 'Turesky Index'). The study was designed to ensure at least 40 subjects completed all treatments. This size was calculated to provide a 90% chance of detecting a difference in Turesky Index of 0.16 as significant at the 5% level. Such a fine level of resolution was desired due to the relatively small intervals between brushing times. This calculation assumed a within-subject standard deviation of 0.3, which was the value determined in a pilot study of plaque removal after 2 minutes brushing with dentifrice (data on file, GSK). Forty-seven subjects were recruited by Hill-Top Research, Cincinnati, from the local population. Recruitment to the panel pre-screening was achieved by advertisements in local media and via the Hill-Top Research Web site, without any restrictions beyond being adult. The subjects (37 female, 10 male), ages 18-63 years, who qualified with a minimum plaque score of 2.0 using the above index were randomized, and 46 returned for at least 1 evaluation (the intent-to-treat population). Subjects were screened to ensure that at least 20 gradable teeth were present and that subjects were in good general physical and oral health with no pathoses.

The subjects brushed with an Aquafresh Flex® flat-trim soft toothbrush and Aquafresh Advanced® (1100 ppm fluoride as sodium fluoride) dentifrice for different defined times, using 1.5g or no dentifrice, in a randomized order. Subjects brushed their teeth at the study site (Hill Top Research, Cincinnati) under supervision on a total of 6 occasions. Brushing times were 30 seconds, 45 seconds, 60 seconds, 120 seconds, and 180 seconds. For the 30-, 45-, 120-, and 180-second brushing, 1.5g (weighed to within +0.05g) of paste was used for each treatment arm. For the 60-second brushing time, there were 2 treatment arms, one using 1.5g dentifrice and the other brushing without dentifrice. Brushing times were assigned in a randomized order over a 3-week period. A minimum washout period of 72 hours was observed between treatments with subjects refraining from brushing for approximately 24 hours prior to each treatment visit.

The study aimed to measure plaque removal achieved by subjects via manual tooth brushing for different brushing times. Dental plaque on the subject's teeth before brushing was disclosed using Butler Red Cote® disclosing solution and the level of plaque was evaluated and recorded using the Turesky Index. The appropriate amount of dentifrice was dispensed by the study technician onto a new toothbrush. Subjects were informed immediately in advance of each brushing occasion how long they were to brush, and the brushing time was divided evenly between the 4 dental quadrants. Brushing time was measured by the technician using a count-down timer. No other modification to the subject's brushing style was made. Dental plaque remaining on the subject's teeth after brushing was re-disclosed and the level evaluated and recorded as before. The amount of plaque removed by brushing was calculated by difference. At each visit, a single examiner conducted an oral soft tissue exam to monitor adverse events.

Data Analysis

Plaque was assessed at 6 sites for each individual tooth. A whole-mouth average score was calculated by summing the individual scores across all teeth and dividing by the number of gradable sites using all non-missing values. The intent-to-treat study population, defined as all subjects who were randomized, treated at least once, and provided at least 1 plaque removal measure, was used for all data analysis. Missing data was not included in the statistical data analysis.

An analysis of covariance model was used to analyze the change from pre-brushing Turesky Index scores. The model included fixed factors for study period and treatment and the random factor subject. The pre-brushing Turesky Index score measured at the start of each study period was included in the model as a covariate. All statistical tests of hypothesis employed a level of significance of 0.05.

Results

Figure 1 shows the change in mean Turesky Index score from pre- to post-brushing as a function of brushing time for the subjects using dentifrice in this crossover study.

A clear dose-response relationship between plaque removal and brushing time was observed. The profile was broadly hyperbolic in form, ie the amount of plaque removed was highly dependent on brushing time at shorter times, but tended towards a maximum at longer times. Howev-

er, even after 3 minutes of brushing, some plaque removal still appeared to be occurring.

The longest brushing time (180 seconds) removed 55% more plaque than the shortest (30 seconds, p<0.0001). A brushing time of 2 minutes removed 26% more plaque than a time of 45 seconds (p=0.0002). Table 1 gives the details of the statistics for brushing time and dose comparisons.

Table 2 shows the actual amounts of plaque present (Turesky Index score) before and after brushing, from which the Table 1 data was calculated. This table indicates that even after the longest brushing times, considerable amounts of plaque remain (3 minutes brushing reduces the mean Turesky Index score from 3.0 to 2.0).

The tables further show there was no statistically significant difference in mean plaque removed between brushing with 1.5g of dentifrice compared to brushing without dentifrice, when brushing time was 60 seconds (0.82 and 0.84 mean Turesky model adjusted units of plaque removed, respectively; p=0.5675).

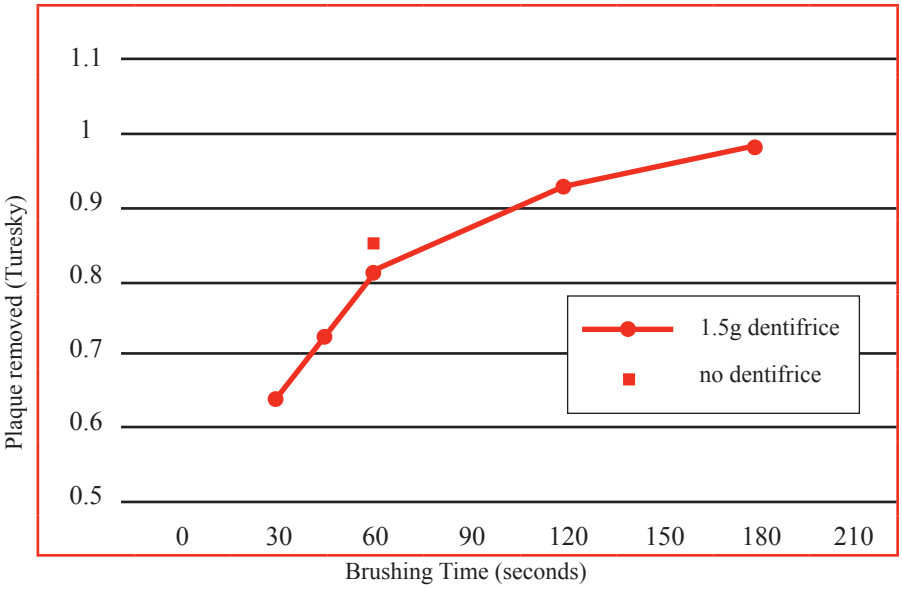

Figure 1. The effect of brushing time and presence of dentifrice on plaque removal, mean ± between subject s.e. (note the 'no dentifrice-60 seconds' value is slightly displaced on the x-axis for clarity).

Table 1. Pair-wise comparisons between treatment groups of change in plaque level during brushing.

Treatment Groups Compared		Adjusted Means (Group 1 - Group 2)[a]		Significance of difference (p-value)
Group 1	Group 2	Difference[b]	95% Conf. Int.[b]	
30 Sec. – 1.5g	45 Sec. – 1.5g	-0.09	[-0.19, 0.01]	0.0838
30 Sec. – 1.5g	60 Sec. – 1.5g	-0.18	[-0.28, -0.08]	0.0005
30 Sec. – 1.5g	120 Sec. – 1.5g	-0.28	[-0.38, -0.18]	<.0001
30 Sec. – 1.5g	180 Sec. – 1.5g	-0.35	[-0.45, -0.25]	<.0001
45 Sec. – 1.5g	60 Sec. – 1.5g	-0.09	[-0.19, 0.01]	0.0721
45 Sec. – 1.5g	120 Sec. – 1.5g	-0.19	[-0.29, -0.09]	0.0002
45 Sec. – 1.5g	180 Sec. – 1.5g	-0.26	[-0.36, -0.16]	<.0001
60 Sec. – 1.5g	120 Sec. – 1.5g	-0.10	[-0.20, -0.00]	0.0454
60 Sec. – 1.5g	180 Sec. – 1.5g	-0.17	[-0.27, -0.07]	0.0008
120 Sec. – 1.5g	180 Sec. – 1.5g	-0.07	[-0.17, 0.03]	0.1715
60 Sec. – 1.5g	60 Sec. – 0.0g	-0.03	[-0.13, 0.07]	0.5675

[a] Least squares means from analysis of covariance with treatment and period as fixed effect, subject as random effect and pre-brushing Turesky index score as a covariate as predictor terms.

[b] Difference in adjusted means; negative values favor the second treatment group.

Discussion

In this study, subjects were enrolled from the general population local to the study site. Subjects used a flat-trim, soft, manual brush and sodium fluoride-silica dentifrice, and were asked to use their normal brushing technique. The choice of brushing times was intended to span the range employed by the large majority of the population, and to include evenly spaced intermediate times to allow for a more complete understanding of the influence of brushing time on plaque removal. Subjects were also told in advance how long they were to brush, were able to adapt their rate of tooth surface coverage accordingly, and were prompted when to change quadrants. The aim of this approach was to model as closely as possible subjects' likely brushing technique, were they actually to brush for the different lengths of time in their normal routine. At the same time, this approach allowed precise control of brushing time and measurement of plaque levels. The design of the study did not include any measures (beyond brushing time) of the brushing procedure used by the individual subjects, so no comment may be made on the effects of brush-

ing technique on plaque removal. A crossover design was used to allow treatment comparisons on a within-subject basis, to minimize the impact of the subjects' different brushing techniques on the ability to detect treatment differences. The analysis was performed on the intent-to-treat population, to represent the real-world situation more closely than a per-protocol analysis.

There were no recruitment restrictions on subjects beyond age, general/oral health, and presence of a sufficient number of gradable teeth with a sufficiently high total plaque score. The population was necessarily restricted by the demographics of the locality, and having the time to attend the clinics. It was clearly biased towards females. The absence of other restrictions leads the authors to believe the population was representative of the locality, and the results relevant to Western developed countries in general.

Given these considerations, the results show brushing time is likely to be an important determinant of plaque removal in the general population. The degree of plaque reduction was related to brushing time across the examined 30-second to 3-minute time period. Plaque removal was dependent on brushing time at shorter times, but tended towards a maximum at extended times. This hyperbolic profile is consistent with a situation in which a proportion of the plaque is relatively easily accessible on the tooth and remaining plaque is progressively less accessible. In this situation, the easily accessible proportion is removed efficiently and quickly. However, the less-accessible remaining plaque is removed at a slower rate. Therefore, a given plaque removal increment will take progressively longer to achieve as brushing proceeds. At extended brushing times, it is also likely that subjects will re-trace the path of previous brushing strokes and remove no further plaque.[14]

The difference between immediately adjacent brushing times up to 2 minutes was of borderline statistical significance. A larger population would likely be required to determine dependency of plaque removal on brushing time to such a high precision.

The central aim of the study was to understand the overall effect of brushing time on plaque removal. Within this broad aim, a key comparison was the effect of brushing for 45 seconds, an estimate of the average brushing time employed by individuals,[33] with the effect of brushing for 2 minutes, a consensus minimum brushing time recommended by oral health professionals. The results showed that 2 minutes brushing removed 26% more plaque than brushing for 45 seconds (p=0.0002).

The profile of plaque removal as a function of time reported here is consistent with that reported by Hawkins et al[15] for dental student subjects trained in the Bass technique, and by McCracken et al[19] for power brush users. In contrast, Klukowska et al[37] showed no evidence of increased plaque removal beyond 1 minute, though in this study, participants did not know until they were stopped how long they had to brush. Hodges et al,[14] in a study performed on children, also saw no benefit of brushing for longer than 1 minute.

Table 2 shows the actual Turesky Index plaque scores before and after brushing for all treatment groups. This indicates that even when brushing for the longest period of the study (3 minutes), subjects left plaque remaining. The mean Turesky Index score after this brushing time was 2.0. As an individual reading, this corresponds to a thin continuous band of plaque around the cervical margin. Other studies of supervised manual brushing have also found that plaque removal is far from complete during 1 brushing session.[13,38-40]

The presence of dentifrice during brushing made no difference to the amount of plaque removed by brushing (Figure 1). The benefit of toothpaste in removing plaque during brushing has been controversial. Reports of improved plaque removal when toothpaste is present[41] have been balanced by reports of no effect,[42] but these reports now contrast with recent work by Paraskevas and coworkers[40,43] which indicate a slight negative effect of the presence of toothpaste. The present study supports the view that the effectiveness of plaque removal during toothbrushing with dentifrice is essentially a function of access of brush bristles rather than dentifrice abrasive.

This study examined plaque removal from a single brushing. It did not examine the effects of brushing for different times or with different dentifrice doses over a period of time, during which cumulative

Table 2. Actual Turesky Index plaque scores before and after brushing as a function of brushing time and presence of dentifrice.

Brushing time	30 Sec.	45 Sec.	60 Sec.	120 Sec.	180 Sec.	60 Sec.
Weight of dentifrice	1.5g	1.5g	1.5g	1.5g	1.5g	0.0g
N	42	43	44	42	42	43
Pre-brushing plaque score (mean ± s.d.)	2.95 ± 0.51	2.98 ± 0.49	2.95 ± 0.49	2.98 ± 0.47	3.00 ± 0.46	2.98 ± 0.53
Post-brushing plaque score (mean ± s.d.)	2.31 ± 0.60	2.26 ± 0.58	2.14 ± 0.57	2.06 ± 0.54	2.01 ± 0.63	2.13 ± 0.60

benefits may become apparent. The study did not address gingivitis, the next stage in dental plaque-related disease. Of particular interest would be to study the hypothesis that maintaining a longer brushing time for an extended period (weeks or months) would result in larger differences in plaque levels than were observed in the present, single-use study. The time-scale of such a study would also allow study of the effect of brushing time and dentifrice dose on gingivitis development.

Conclusion

Plaque removal during toothbrushing, by untutored subjects recruited from the general population local to the study site, was strongly dependent on brushing time. Increasing brushing time increased plaque removal across the period 30 seconds to 3 minutes. Plaque removal was, however, not influenced by the presence of dentifrice (over 60 seconds brushing), indicating that dentifrice constituents, such as abrasive and surfactant, do not meaningfully assist the action of the brush. A key finding in this study was that brushing for 2 minutes gave a 26% improvement in plaque removal compared to brushing for 45 seconds. This represents the plaque removal benefit individuals should expect when increasing their brushing time from the average 45 seconds[33] to the consensus minimum of 2 minutes. Though lower plaque levels as a result of more effective brushing may not always lead to a reduction in gingivitis,[5,44-47] this degree of improvement is potentially of clinical significance in reducing the risk of gingival disease. These results reinforce the view that oral health professionals, while coaching their patients in brushing technique, should recommend brushing for at least 2 minutes.

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