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

Andrew Gallagher, DMD; Joseph Sowinski, DDS; James Bowman, MS; Kathy Barrett; Shirley Lowe; Kartik Patel, PhD; Mary Lynn Bosma, DDS; Jonathan E Creeth, PhD

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
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 of the original index of Quigley and Hein, as modified subsequently by Lobene et al 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 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).

**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-

**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.

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

[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.
The difference between immediate 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, 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 for dental student subjects trained in the Bass technique, and by McCracken et al for power brush users. In contrast, Klukowska et al 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, 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 as a function of brushing time and presence of dentifrice.

<table>
<thead>
<tr>
<th>Brushing time</th>
<th>30 Sec.</th>
<th>45 Sec.</th>
<th>60 Sec.</th>
<th>120 Sec.</th>
<th>180 Sec.</th>
<th>60 Sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of dentifrice</td>
<td>1.5g</td>
<td>1.5g</td>
<td>1.5g</td>
<td>1.5g</td>
<td>1.5g</td>
<td>0.0g</td>
</tr>
<tr>
<td>N</td>
<td>42</td>
<td>43</td>
<td>44</td>
<td>42</td>
<td>42</td>
<td>43</td>
</tr>
<tr>
<td>Pre-brushing plaque score</td>
<td>2.95 ± 0.51</td>
<td>2.98 ± 0.49</td>
<td>2.95 ± 0.49</td>
<td>2.98 ± 0.47</td>
<td>3.00 ± 0.46</td>
<td>2.98 ± 0.53</td>
</tr>
<tr>
<td>Post-brushing plaque score</td>
<td>2.31 ± 0.60</td>
<td>2.26 ± 0.58</td>
<td>2.14 ± 0.57</td>
<td>2.06 ± 0.54</td>
<td>2.01 ± 0.63</td>
<td>2.13 ± 0.60</td>
</tr>
</tbody>
</table>

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 have been balanced by reports of no effect, but these reports now contrast with recent work by Paraskevas and coworkers 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
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 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, 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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**Disclosure:** Several of the authors are employed by GlaxoSmithKline, who are the manufacturers of Aquafresh products used in this study.

**References**


