Effectiveness of a motionless ultrasonic toothbrush in reducing plaque and gingival inflammation in patients with fixed orthodontic appliances

Thayika Saruttichart; Pintu-on Chantarawaratit; Chalermpol Leevailoj; Panida Thanyasrisung; Waranuch Pitiphate; Oranart Matangkasombut

ABSTRACT

Objective: To compare the effectiveness of a motionless ultrasonic toothbrush to a manual toothbrush in reducing dental plaque, gingival inflammation, and mutans streptococci in patients with fixed orthodontic appliances.

Materials and Methods: Twenty-five orthodontic patients were recruited to this crossover study. The patients were randomized into two groups starting with manual or motionless ultrasonic toothbrushes for 30 days. After a 30-day washout period, the patients switched to the other toothbrush type for 30 days. Plaque and gingival indices were evaluated by two calibrated-blinded examiners before and after each 30-day period of brushing. Salivary samples were also collected for quantification of mutans streptococci.

Results: On the bracket side, the motionless ultrasonic toothbrush showed a significantly higher mean plaque index bracket score after 30-day usage than baseline ($P = .049$), while the manual toothbrush group showed no difference between the before and after brushing periods ($P = .10$). The changes in plaque index bracket score were significantly more favorable in the manual toothbrush group than in the ultrasonic toothbrush group ($P = .04$). In contrast, no difference was observed on the nonbracket side. There was no significant difference in the changes of gingival index or the numbers of mutans streptococci between the two groups.

Conclusion: Manual toothbrushing performed better than brushing with the motionless ultrasonic toothbrush in plaque removal on the bracket side in orthodontic patients. However, no difference was observed in terms of gingival status and the numbers of mutans streptococci. (Angle Orthod. 2017;87:279–285)

KEY WORDS: Motionless ultrasonic toothbrush; Powered toothbrush; Dental plaque removal; Fixed orthodontic appliances; Gingival inflammation; Mutans streptococci

INTRODUCTION

Dental plaque is the primary factor causing dental caries and periodontal diseases; thus, its removal by effective toothbrushing plays an important role in preventing these conditions.$^1$ This is especially crucial in orthodontic patients, who have greater difficulties in
maintaining oral hygiene due to the presence of orthodontic brackets and wires. Changes in pH and microbial populations in dental plaque have been observed after orthodontic appliance placement; these could lead to oral pathology. Recent studies showed that approximately 25% of patients undergoing orthodontic treatment developed one or more decalcifications during the treatment course. Moreover, fixed orthodontic treatment can increase gingival inflammation, bleeding, enlargement, and probing depth. These further emphasize the importance of effective toothbrushing for orthodontic patients.

Because of the difficulties in plaque removal in patients with fixed orthodontic treatment, powered toothbrushes have been proposed as an alternative to manual toothbrushes. A recent systematic review suggests that there is moderate-quality evidence that powered toothbrushes perform better than manual toothbrushes in reducing plaque and gingivitis. However, not a large number of trials have been performed in orthodontic patients; these studies also tested different types of powered toothbrushes and observed conflicting results. Thus, whether and which type of powered toothbrushes may be beneficial for orthodontic patients remains unclear.

Among various types of powered toothbrushes, existing evidence suggested that rotation-oscillation, ionic, and ultrasonic brushes performed better than manual toothbrushes in plaque reduction, with the most evidence existed for the rotation-oscillation brushes. Ultrasonic brushes use ultrasonic wave to aid in plaque removal. They have been shown to remove significantly greater in vitro Streptococcus mutans biofilm from hydroxyapatite surfaces without bristle contacts compared with rotation-oscillation toothbrushes. Recently, a motionless ultrasonic toothbrush (Emmi-dent) has been introduced with objectives to overcome tooth wear and tissue damage caused by manual and motor-driven toothbrushes and to reduce plaque in difficult to clean areas. However, no clinical evidence exists on its effectiveness, especially in orthodontic patients.

Therefore, this study was conducted to compare the effectiveness of the motionless ultrasonic toothbrushes and manual toothbrushing in terms of plaque removal, reduction in gingival inflammation, and numbers of mutans streptococci in patients with fixed orthodontic appliances.

**MATERIALS AND METHODS**

The study was carried out as a randomized controlled trial with a single-blind two-treatment cross-over design. The study protocol was approved by the ethics committee at Faculty of Dentistry, Chulalongkorn University (approval no.031/2015, study code: HREC-DCU2015-001) and registered at the Thai Clinical Trials Registry (TCTR; TCTR20151123003).

The sample size was calculated using plaque index data from a previous study on ultrasonic toothbrushes with an alpha of 0.05 and 0.8 power of test for a two-sided test. Twenty-five participants who underwent orthodontic treatment with fixed appliances at the orthodontic clinic at Chulalongkorn University during April through December 2015 were recruited according to the eligibility criteria (Table 1). All participants, or their parents in the case of those younger than 18 years of age, gave written informed consent before beginning this study.

**Study Method**

Filling (if needed) and scaling were given to all participants 1 month before the beginning of the study. At the start date, baseline data were collected for plaque index, gingival index, and microbiological evaluation. The participants were randomized by block randomization into two groups: A (manual/ultrasonic) and B (ultrasonic/manual) (Figure 1).

Participants in group A were each given an orthodontic toothbrush (Systema OD, Lion Company, Tokyo, Japan) and a 5-minute instruction on the Bass technique from one trained dentist. Group B obtained a motionless ultrasonic toothbrush (Emmi-dent Emmi Ultrasonic Co, Morfelden-Waldorf, Germany) with a brushhead for braces and an instruction according to the manufacturer. Briefly, the brush is held on the tooth surfaces without moving or applying pressure for 5–10 seconds at each position covering 2–3 teeth. Both groups were assigned to use each technique for 30 days, during which the participants were instructed to...
refrain from using other oral hygiene aids or mouth rinses. After this time, the patients returned to their regular toothbrushes in a 30-day washout period, and then switched to using the other device for 30 days. They were evaluated at the beginning and at the end of the 30-day period of each intervention by two calibrated examiners who were blinded to the intervention. All participants were regularly monitored by a weekly phone call to determine if they used the toothbrushes correctly.

Clinical Evaluation

Before the study started, two trained examiners were calibrated for the evaluation of plaque index bracket (PIB) and gingival index (GI) by examining both indices on three patients with fixed orthodontic appliances. Kappa statistic was used to evaluate the intraexaminer and interexaminer reliability. For PIB and GI, the $\kappa$ was 0.79–0.89 for intraexaminer reliability and 0.77–0.89 for interexaminer reliability.

Plaque Index Bracket

The previously described modified plaque index (PI) for orthodontic patients, PIB,16 was evaluated on the bracket sides of one representative tooth from six sextants: upper right (first molar), upper center (central incisor), upper left (first molar), lower right (first molar), lower center (central incisor), and lower left (first molar). Each tooth was divided into four zones according to the position around the brackets (mesial [M], distal [D], gingival [G], and incisal [I]; Figure 2) and evaluated according to the PI score of Loe and Silness.17 In cases where the first molar was banded or missing, the second premolar was chosen to represent the sextant. On the nonbracket side, the Loe and Silness PI was used.17

Gingival Index Score

The gingival condition of each tooth was examined by the calibrated dentists using a periodontal probe and recorded according to the GI, as described.17

Microbiological Evaluation

Samples of stimulated saliva (5 mL) were collected in the morning before brushing. The salivary samples were transported to the laboratory, serially diluted, and cultured on Mitis Salivarius-Bacitracin agar. The colonies of mutans streptococci were counted after a 48-hour incubation under 5% carbon dioxide. The number of colony forming units (CFUs) in 1 mL of saliva was calculated by dilution factors and converted into logarithmic form (logCFU/mL) for further analysis.

Statistical Analysis

The data were tested for normality by using Shapiro-Wilk test. We analyzed the differences between the before and after brushing periods (within group) and the changes of the values (after to before) between the two treatment groups using paired t-tests for normally distributed data (GI and logCFU/mL of mutans streptococci) and Wilcoxon signed rank test for skewed data (PI). We also examined the differences between the two toothbrushing groups using two-way repeated measures analysis of variance. Statistically significant difference was set at $P < .05$. All data were included in the analysis according to the intention-to-treat concept.18

RESULTS

A total of 25 subjects (8 males and 17 females) with ages ranged from 13 to 43 years (mean ± standard deviation = 23.3 ± 6.5) were enrolled, and all participants completed both legs of the study.

The presence of visible plaque was examined before and after each experimental period. The mean PI scores of both the bracket and nonbracket sides are shown in Table 2. The PIB scores after the ultrasonic
toothbrushing period were significantly higher than baseline \( (P = .049) \), while there was no significant difference in the manual toothbrushing group \( (P = .104) \). The changes in PIB scores (after to before) were significantly better in the manual toothbrushing group than the ultrasonic toothbrushing group \( (P = .042) \). Furthermore, when various positions on the tooth were analyzed separately, a significant increase in the PIB scores after ultrasonic toothbrush use and a significant difference in the changes of PIB scores between the two toothbrushing groups were observed for all sites (Table 3). In contrast, on the nonbracket side, both toothbrushing groups show no significant difference in PI score in both within-group and between-group comparisons (Table 2). Likewise, no difference was seen in the comparisons of GI scores before and after each intervention or in the changes in GI scores between the two toothbrushing groups (Table 4). Additional analyses with two-way repeated measures analysis of variance showed consistent results.

The microbiological data were obtained from 16 subjects because the numbers of mutans streptococcal colonies could not be counted in at least one of the four collections, leading to incomplete data for nine subjects. The geometric means of mutans streptococcal numbers showed no difference before and after the brushing periods for both groups. No significant difference in bacterial counts was observed between the two groups, either before or after the brushing period (Table 5).

In addition, one male participant (group B) had a mild burning sensation on his lip and chin with redness on his chin after contact with the nano-bubble toothpaste used with the ultrasonic toothbrush. Thus, he changed to a regular toothpaste with the ultrasonic toothbrush until the 30-day period was over. In addition, one male participant (group B) missed his first follow-up appointment and continued to use the ultrasonic toothbrush for a total of two months. Nevertheless, we included their data in our analyses according to the intention-to-treat concept.

**DISCUSSION**

This randomized controlled study used a crossover design with a 30-day washout period to test the effectiveness of brushing with a recently launched motionless ultrasonic toothbrush in patients with fixed orthodontic appliances. The crossover design offers many advantages because the effects of the two types of toothbrushes can be measured in the same persons. These advantages include a decrease in the number of subjects and within-subject confounding factors (eg, age, gender, and hand skills). However, there are concerns regarding the use of crossover design. To minimize the carryover effect, we allowed for a 30-day washout period when the patients went back to using their normal toothbrushes. Furthermore, to reduce the period effect on the sequence of experimental interventions, we only recruited patients who had had fixed orthodontic appliances for more than 1 month. This was to allow time for the patients to become familiar with brushing with brackets and wires on their teeth, so that the outcomes in patients with different

### Table 2. Mean (Standard Deviation) Plaque Index Score of Bracket and Nonbracket Sides Before and After Each Brushing Period and Their Differences

<table>
<thead>
<tr>
<th>Side</th>
<th>Intervention</th>
<th>N</th>
<th>Before Brushing Period</th>
<th>After Brushing Period</th>
<th>Within-Group ( P ) Value*</th>
<th>Difference Between After and Before Brushing</th>
<th>Between-Group ( P ) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bracket</td>
<td>Manual</td>
<td>25</td>
<td>1.47 (0.55)</td>
<td>1.36 (0.44)</td>
<td>.10</td>
<td>−0.11 (0.30)</td>
<td>.04*</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>25</td>
<td>1.46 (0.48)</td>
<td>1.58 (0.61)</td>
<td>.049*</td>
<td>0.12 (0.33)</td>
<td></td>
</tr>
<tr>
<td>Nonbracket</td>
<td>Manual</td>
<td>25</td>
<td>1.99 (0.59)</td>
<td>2.03 (0.54)</td>
<td>.43</td>
<td>0.05 (0.73)</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>25</td>
<td>1.99 (0.49)</td>
<td>2.06 (0.37)</td>
<td>.77</td>
<td>0.07 (0.42)</td>
<td></td>
</tr>
</tbody>
</table>

* Wilcoxon signed rank test; \* Statistically significant difference \( P < .05 \).

### Table 3. Mean (Standard Deviation) Plaque Index Score of Various Positions on the Tooth Surface on the Bracket Side Before and After Each Brushing Period and Their Differences

<table>
<thead>
<tr>
<th>Site</th>
<th>Intervention</th>
<th>N</th>
<th>Before Brushing Period</th>
<th>After Brushing Period</th>
<th>Within-Group ( P ) Value*</th>
<th>Difference Between After and Before Brushing</th>
<th>Between-Group ( P ) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bracket</td>
<td>Proximal</td>
<td>25</td>
<td>2.28 (0.39)</td>
<td>2.18 (0.43)</td>
<td>.196</td>
<td>−0.09 (0.40)</td>
<td>.002*</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>25</td>
<td>2.19 (0.35)</td>
<td>2.53 (0.31)</td>
<td>&lt;.001*</td>
<td>0.35 (0.35)</td>
<td></td>
</tr>
<tr>
<td>Gingival</td>
<td>Manual</td>
<td>25</td>
<td>2.06 (0.49)</td>
<td>1.94 (0.51)</td>
<td>.090</td>
<td>−0.12 (0.5)</td>
<td>.006*</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>25</td>
<td>1.94 (0.52)</td>
<td>2.27 (0.40)</td>
<td>.004*</td>
<td>0.32 (0.49)</td>
<td></td>
</tr>
<tr>
<td>Incisal</td>
<td>Manual</td>
<td>25</td>
<td>1.00 (0.51)</td>
<td>0.76 (0.50)</td>
<td>.181</td>
<td>−0.23 (0.57)</td>
<td>.009*</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>25</td>
<td>0.91 (0.43)</td>
<td>1.25 (0.49)</td>
<td>.005*</td>
<td>0.33 (0.50)</td>
<td></td>
</tr>
</tbody>
</table>

* Wilcoxon signed rank test; \* Statistically significant difference \( P < .05 \).

a Proximal is the average of mesial and distal plaque index score.
experimental sequences would not be affected by the time-dependent acquisition of brushing skills. Randomization was also used to minimize the sequence effect due to changes in malocclusion or brushing technique over time. The interventions were performed at home to mimic normal conditions, and participants received weekly monitoring phone calls to maximize compliance.

Our results suggest that on the bracket side, the motionless ultrasonic toothbrush group had increased plaque accumulation compared with the manual toothbrush group (Table 2). The mean PIB scores of all sites (proximal, incisal, and gingival areas) were increased significantly after using the motionless ultrasonic toothbrush, whereas no significant difference was detected in the manual group (Table 3). Between-group comparisons also showed significant differences at all sites. The manufacturer claims that the motionless ultrasonic toothbrush could provide 96-million air oscillations/minute to remove dental plaque without any bristle movement. However, according to our results, this may not be enough to reduce plaque accumulation in difficult to clean areas, such as around orthodontic brackets, although the motionless ultrasonic toothbrush group performed similarly to the manual toothbrush on the nonbracket side. This result is supported by a previous study indicating that placing an ultrasonic toothbrush 3 mm from tooth surfaces was not effective for plaque removal in vivo, even though it has been shown to be effective in vitro.

Theoretically, the ultrasonic waves could remove adhered bacteria and may induce cell surface alterations that affect plaque attachment. While a number of studies showed that ultrasonic toothbrushes could reduce more dental plaque and/or mutans streptococci than manual brushes, no significant difference was observed in other reports. Costa and coworkers found no significant difference in the prevalence and levels of several oral bacterial species after use of ultrasonic toothbrushes. Although an earlier study reported a significant reduction in mutans streptococci numbers in the ultrasonic group, the differences in the bacterial counts (CFU/mL) presented were minor for microbiological data. Since a high risk for caries is associated with >10^3 CFU/mL of salivary mutans streptococci and low risk with <10^4 CFU/mL, large changes in mutans streptococci number (in the level of orders of magnitude) would be necessary to affect caries risk. Furthermore, because of the highly skewed nature of microbial count data, we performed logarithmic transformation of CFU/mL so that the data have normal distribution for statistical analysis. The data reported here by geometric means and 95% confidence intervals (Table 5) are more suitable to represent the distribution of bacterial counts. However, our study suffered from a limitation of the crossover design, where missing only one of four measurements meant that we lost the whole set of data. Due to this limitation, we could obtain complete data from only 16 subjects, and this may affect the power of the analysis.

In our study, we did not observe significant reduction in the PIB and PI scores before and after the brushing periods. This could be due to the Hawthorne effect that may have started 1 month before the experimental period when the patients were given oral prophylaxis and oral care instructions. This may also, at least partly, explain why we observed no difference in the gingival conditions. Furthermore, although the increase in visible plaque on the bracket side was observed in the ultrasonic group, the GI scores were not effective for plaque removal in vivo, even though it is supported by a previous study indicating that placing a manual toothbrush on the nonbracket side. This result shows that the motionless ultrasonic toothbrush could provide 96-million air oscillations/minute to remove dental plaque without any bristle movement.

### Table 4. Mean (Standard Deviation) Gingival Index Score of Bracket and Nonbracket Sides Before and After Each Brushing Period and Their Differences

<table>
<thead>
<tr>
<th>Side</th>
<th>Intervention</th>
<th>N</th>
<th>Before Brushing Period</th>
<th>After Brushing Period</th>
<th>Within-Group P Value</th>
<th>Difference Between After and Before Brushing</th>
<th>Between-Group P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bracket</td>
<td>Manual</td>
<td>25</td>
<td>1.04 (0.16)</td>
<td>1.08 (0.14)</td>
<td>.228</td>
<td>.04 (0.19)</td>
<td>.24</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>25</td>
<td>1.12 (0.23)</td>
<td>1.09 (0.16)</td>
<td>.586</td>
<td>–0.02 (0.26)</td>
<td>.24</td>
</tr>
<tr>
<td>Nonbracket</td>
<td>Manual</td>
<td>25</td>
<td>1.08 (0.18)</td>
<td>1.13 (0.12)</td>
<td>.116</td>
<td>.05 (0.18)</td>
<td>.24</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic</td>
<td>25</td>
<td>1.14 (0.19)</td>
<td>1.12 (0.13)</td>
<td>.647</td>
<td>–0.02 (0.24)</td>
<td>.24</td>
</tr>
</tbody>
</table>

* Paired t-tests.

### Table 5. Numbers of Mutans Streptococci Before and After Each Brushing Period

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Before Brushing Period (×10^5 CFU/mL)</th>
<th>After Brushing Period (×10^5 CFU/mL)</th>
<th>Within-Group P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (95% CI)</td>
<td>Geometric Mean (95% CI)</td>
<td></td>
</tr>
<tr>
<td>Manual</td>
<td>4.6 (0.8, 9.7)</td>
<td>0.7 (0.2, 1.9)</td>
<td>.24</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>4.1 (1.4, 7.4)</td>
<td>0.8 (0.3, 2.2)</td>
<td>.90</td>
</tr>
<tr>
<td>Between-group</td>
<td></td>
<td></td>
<td>.75</td>
</tr>
</tbody>
</table>

* CFU indicates colony-forming unit; CI, confidence interval.

* Paired t-test (using logCFU/mL data; logCFU/mL = Base 10 logarithmic of CFUs per milliliter).
showed no significant difference. Previous studies indicated that gingivitis usually develops after 15–21 days of complete withdrawal of oral hygiene care and a change of 0.2 PI units predicts a statistically significant difference of 0.1 unit in the GI score. The level of plaque increase in the ultrasonic group in this study may not be enough to significantly affect the GI scores. Another possible reason is that our participants were given oral hygiene instructions at the start of orthodontic treatments and again before each study period. A recent trial in orthodontic patients suggested that repeated oral hygiene motivation leads to successful plaque control regardless of the types of toothbrushes used.

Previous studies of powered toothbrushes in orthodontic patients yielded different results, so it is not yet conclusive if they perform better than manual toothbrushes. The majority of studies tested the effectiveness of rotation-oscillation toothbrushes. Our study added to the evidence that the new motionless ultrasonic toothbrush was not as effective as manual toothbrushing in reducing dental plaque on the bracket side. Nevertheless, it showed a comparable result on the nonbracket side. This implies that the motionless ultrasonic toothbrush may be more suitable for non-orthodontic patients. It may be beneficial for patients lacking manual dexterity, but this issue needs further investigation.

CONCLUSION

• In this study, manual toothbrushes performed better than motionless ultrasonic toothbrushes in dental plaque removal on the bracket side, but there was no difference between the two groups on the nonbracket side in orthodontic patients with fixed appliances.
• No difference was observed with regards to gingival condition and number of mutans streptococci.

ACKNOWLEDGMENTS

The authors sincerely thank Associate Professor Dr Suphot Tamsaim for advice on clinical evaluations. We are grateful to all participants in the study, and to Ms Wanpen Sinheng and members of Department of Microbiology and Orthodontics clinic for their kind help. This study was supported by Chulalongkorn University graduate school thesis grant and Ratchadaphiseksomphot Endowment Fund (to R.U. on oral microbiology and immunology). The motionless ultrasonic toothbrushes were kindly provided by Zione Corporation Co, Ltd.

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