Original Article

Efficacy of Ultrasonic, Electric and Manual Toothbrushes in Patients with Fixed Orthodontic Appliances

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ABSTRACT

Objective: This crossover study compared the efficacy of an ultrasonic toothbrush for the reduction of plaque, gingival inflammation, and levels of *Streptococcus mutans*, in relation to an electric and a manual toothbrush.

Materials and Methods: Twenty-one patients with orthodontic appliances were divided into three groups. All patients were evaluated by a periodontist and samples of saliva were collected for quantification of *S mutans*. The patients received their first brushes with appropriate instructions. For each crossover leg, patients used each toothbrush for a period of 30 days. At the end of each washout period, participants received a periodontal evaluation and new samples of saliva were collected. After 15 days of using their own toothbrushes, patients received the next toothbrushes in the experimental sequence.

Results: The ultrasonic brush group presented significant improvement in the reduction of visible plaque on the buccal surfaces (−6.36%, $P = .007$). The counts of *S mutans* decreased in the electric (2.04×10^5 to 1.36×10^5 colony-forming units [CFU]/mL) and ultrasonic (2.98×10^5 to 1.84×10^5 CFU/mL) groups. There were no statistical differences among the three brushes for the clinical and microbiological parameters evaluated.

Conclusions: This study did not demonstrate that the ultrasonic toothbrush was better in reducing gingival inflammation in adolescent orthodontic patients, but plaque scores were lowered on buccal surfaces of teeth with orthodontic brackets. In addition, *S mutans* counts were markedly decreased in the electric and ultrasonic groups, which should be related to a reduced risk of oral disease.

KEY WORDS: Electric toothbrushes; Fixed orthodontic appliance; Oral hygiene; *Streptococcus mutans*

INTRODUCTION

Bacteria present in dental plaque are recognized as the principal cause of caries and periodontal disease. Therefore, prevention and treatment of these two diseases are based mainly on dental plaque removal. Removal by professional scaling and prophylaxis is the most effective method to reduce pathogenic organisms and promote oral health.[1] However, personal oral hygiene, using a toothbrush and dental floss daily, is crucial for satisfactory maintenance.

Those undergoing orthodontic treatment have greater difficulty with such hygiene. Orthodontic bands, brackets, and wires are impediments to brushing and flossing, frequently facilitating accumulation of plaque to jeopardize gingival health. Orthodontic treatment with fixed appliances can increase inflammation, bleeding, and enlargement of the gingiva, as well as increasing probing pocket depth.[2]

Microbiological changes have also been associated

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with these appliances. Studies indicated an increase in *Streptococcus mutans* and lactobacilli after the bonding of fixed appliances.[3] Other experiences reveal a statistically significant increase in suspected periodontal pathogens such as spirochetes, motile rods, and other gram-negative organisms.[4]

Therefore, effective brushing of teeth is important as a preventive measure. In this context, many types of toothbrushes, both manual and powered options, have been promoted for orthodontic patients. However, no study has reported comparison of the efficacy of an ultrasonic toothbrush used by patients under orthodontic therapy. Also, clinical studies with ultrasonic brushes in patients without orthodontic appliances are inconclusive. When compared with manual brushes,[5] results vary from a significant superiority to minor effects.[6]

This study was conducted to evaluate the efficacy of an ultrasonic toothbrush in reducing plaque, gingival inflammation, and levels of *S mutans*, when compared to an electric and a regular manual toothbrush for adolescent orthodontic patients with fixed appliances.

MATERIALS AND METHODS

Twenty-one patients of ages ranging from 12 to 18 years (mean 15.2 years; 11 male and 10 female) undergoing orthodontic treatment in the School of Dentistry at Araraquara (São Paulo, Brazil), were selected for this study. They had at least 20 teeth and had been under orthodontic treatment with fixed appliances for a minimum of a year. All were nonsmokers with no obvious periodontal disease or loss of attachment. They had not taken medication in the last 3 months and had no systemic or local disease affecting the periodontium.

According to the protocol of the orthodontic clinic, all patients received plaque control and instructions in oral hygiene before beginning treatment and were regularly evaluated for periodontal condition during the treatment.

Study Method

This crossover study was approved by the Ethics and Research Committee of the School of Dentistry (protocol number 03/03). Informed consent was obtained by all participants and their parents before the onset of the study.

The ultrasonic brush tested was the Ultrasonex Ultima Toothbrush® (Sonex International Corp, Brewster, New York), which has a removable center head and operates at a frequency of 1.6 MHz. Comparisons were made with an electric brush (Braun Oral B 3D Plaque Remover, Braun GmbH, Kronberg, Germany) and a manual brush (Oral B Model 30, Gillete do Brasil, Manaus, Brazil).

The participants were randomly divided into three groups and assigned sequences of brush use as follows:

- Group 1: ultrasonic/electric/manual;
- Group 2: manual/ultrasonic/electric;
- Group 3: electric/manual/ultrasonic.

The subjects used each assigned brush for a period of 30 days, followed by an interval of 14 days during which they returned to their regular toothbrushes and dental floss used in accordance with the monthly instructions of the orthodontist given prior to the study. They were evaluated at the end of morning or afternoon periods with 3–5 hours of plaque accumulation both at baseline and at the end of every 30-day period.

During baseline visits, subjects were instructed in oral hygiene techniques. For those receiving a manual brush, the Bass technique was demonstrated, whereas subjects receiving the electric and ultrasonic versions were given audiovisual presentations of the correct use according to the manufacturer. The subjects were requested to use their assigned toothbrushes three times daily for 2 minutes with the designated toothpaste (Sorriso®, Colgate-Palmolive Indústria e Comércio Ltda., São Bernardo do Campo, SP, Brazil) and to avoid other health products or techniques.

Clinical Parameters

Clinical measurements were performed for all teeth except second and third molars by a blinded trained examiner using a periodontal probe (UNC 1-15, Hu-Friedy, Chicago, Ill). Intraexaminer reliability for index reproducibility was assessed twice during the study on seven patients by repeating a complete mouth plaque index, a gingival index, and probing depth (PD) measurements. The κ score for each measurement was never lower than 0.75.

Following placement of a self-retaining cheek retractor and cotton rolls, plaque was assessed on the buccal surfaces of the teeth using the orthodontic modification (PI)[7] of the Silness and Löe Plaque Index.[8] The plaque component of this index divides the buccal surface of each tooth into four zones according to the position of the orthodontic bracket—incisal, distal, mesial, and gingival to the bracket—and designates codes 0 for absence or 1 for presence of visible plaque. The lingual surfaces were assessed using the Silness and Löe Plaque Index dichotomized for absence and presence of visible plaque. The gingival inflammatory condition was evaluated by the Löe and Silness Gingival Index (GI), dichotomized for presence or absence of bleeding.[9]

PD, corresponding to the distance in mm from gingival margin to the bottom of gingival sulcus, was taken at six sites per tooth (mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual).

Microbiological Parameters

Samples of 1 mL unstimulated saliva were collected from patients at the beginning and end of each 30-day brushing period. These samples were placed in individual sterile tubes. The tubes were sent to the laboratory for processing soon after collection (15 $\pm$ 3 min). They were subjected to vibration (Vortex®, AP-56, Phoenix, Araraquara, SP, Brazil) for 2 minutes and diluted in decimal series from 10^{-1} to 10^{-4} with sterile saline. For cultivation of *S mutans*, aliquots of 25 μL of each dilution were inoculated in duplicate on selective bacitracin sucrose agar (SB20).[10] The two agar plates with each dilution were incubated for 48 hours in candle jars at 37°C.

An electronic colony counter (CP 600 Plus, Phoenix, Araraquara, SP, Brazil) was used to define the number of streptococci colonies (colony-forming units [CFU]/mL). Only agar plates with less than 300 colonies were counted. The mean value of the same dilution with a suitable number of colonies was used to determine the microbial count.

Statistical Analysis

The outcome variables evaluated in this study were changes in the mean clinical and microbiological parameters from baseline to 1 month. For this analysis, data were divided into subgroups according to the types of brush (ultrasonic, electric, or manual) and dental surface (buccal, lingual, or proximal).

The significance of differences over time (baseline to 1 month) within each brushing subgroup was determined using the Wilcoxon test. Differences among subgroups at each time point were determined using the Kruskal-Wallis test. Statistical significance was set at $P < .05$. In order to avoid many spurious positives, the alpha value had to be lowered to account for the number of comparisons being performed. Therefore, the statistical outcome was corrected for multiple tests using the Bonferroni correction.

RESULTS

All 21 patients completed the study with no adverse effects reported by any of the subjects or noted by the examiner. Variations observed in sites with visible plaque (PI) after the use of each brush are shown in Table 1. There was a significant difference for the ultrasonic/buccal group, indicating that the ultrasonic brush improved plaque reduction on the buccal surfaces ($P = .007$, Wilcoxon test).

TABLE 1. Percentages of Sites With Visible Plaque (PI)[a] Before and After the Use of Related Brushes on Different Dental Surfaces

Toothbrush/ Surface	Mean Prebrushing (%)	Mean Postbrushing (%)	Mean Difference (%)	SD (%)	P[b]
E/B	7.60	6.28	1.32	8.69	.47
U/B	10.32	3.96	6.36	10.05	.007*
M/B	14.89	10.39	4.50	15.49	.19
E/L	4.44	2.42	2.02	5.58	.11
U/L	8.67	4.40	4.27	9.35	.06
M/L	8.43	4.82	3.61	8.76	.08

[a] PI indicates the orthodontic modification of the Silness and Loe Plaque Index; E, electric; P, proximal; U, ultrasonic; M, manual; B, buccal; L, lingual.

[b] Wilcoxon test.

* Statistically significantly different, incorporating Bonferroni correction ($P < .05$).

TABLE 2. Percentages of Sites With Marginal Bleeding (GI)[a] Before and After the Use of Related Brushes on Different Dental Surfaces

Toothbrush/ Surface	Mean Prebrushing (%)	Mean Postbrushing (%)	Mean Difference (%)	SD (%)	P[b]
E/P	13	17.22	−4.22	11.47	.13
U/P	18.89	14.83	4.06	16.38	.24
M/P	20.75	17.22	3.53	12.82	.18
E/B	11.15	15.51	−4.36	14.46	.16
U/B	13.74	9.80	3.94	13.29	.13
M/B	17.22	15.22	2	13.28	.33
E/L	19.92	14.93	4.99	13.78	.08
U/L	20.19	18.57	1.62	12.45	.52
M/L	24.84	21.66	3.18	16.45	.22

[a] GI indicates Loe and Silness Gingival Index; E, electric; P, proximal; U, ultrasonic; M, manual; B, buccal; L, lingual.

[b] Wilcoxon test.

Table 2 outlines the variations in marginal bleeding after the use of each brush. No significant differences were noted in the nine subgroups ($P > .05$, Wilcoxon test). PD after the use of each brush is in Table 3. There were no significant differences in the nine subgroups ($P > .05$, Wilcoxon test).

The results for CFU/mL of *S mutans* recovered in SB20 before and after use of the different brushes are shown in Table 4. In the ultrasonic and electric groups, *S mutans* counts decreased significantly after 1 month ($P < .05$, Wilcoxon test).

When the three brush groups were compared for each time point, there were no significant differences in any of the study parameters ($P > .05$, Kruskal-Wallis).

DISCUSSION

This randomized crossover study provides important information on the efficacy of powered ultrasonic

TABLE 3. Mean Probing Depth (mm) Before and After the Use of Related Brushes on Different Dental Surfaces[a]

Toothbrush/ Surface	Mean Prebrushing (mm)	Mean Postbrushing (mm)	Mean Difference (mm)	SD (mm)	P[b]
E/P	2.67	2.65	0.02	0.22	.60
U/P	2.64	2.59	0.05	0.28	.40
M/P	2.64	2.65	−0.01	0.30	.66
E/B	1.89	1.91	−0.02	0.27	.80
U/B	1.89	1.79	0.10	0.30	.12
M/B	1.88	1.91	−0.03	2.26	.69
E/L	1.80	1.73	0.07	0.26	.09
U/L	1.82	1.76	0.06	0.40	.45
M/L	1.83	1.70	0.13	0.29	.05

[a] E indicates electric; P, proximal; U, ultrasonic; M, manual; B, buccal; L, lingual.
[b] Wilcoxon test.

TABLE 4. Bacterial Growth of *Streptococcus mutans* in CFU/ml Before and After the Use of Related Brushes on Different Dental Surfaces[a]

Toothbrush	Mean Prebrushing (CFU/mL)	Mean Postbrushing (CFU/mL)
Electric	2.04×10^5	1.36×10^5*
Ultrasonic	2.98×10^5	1.84×10^5*
Manual	2.12×10^5	2.08×10^5

[a] CFU indicates colony-forming units.
* Statistically significantly different ($P < .05$, Wilcoxon test).

toothbrush when compared to electric and manual toothbrushes for the oral health of orthodontic patients undergoing fixed appliance therapy. A crossover design enabled each brush to be tested by each subject with a washout period between the study periods. This methodology has been used in many comparative toothbrushing studies of orthodontic patients. Some of the advantages presented by those authors include increased sample size and control of confusing variables, such as compliance.[11]

A significant decrease in the percentage of visible plaque (PI) was observed only on the buccal surfaces (10.32% to 3.96%) after use of the ultrasonic brush. Considering that the areas adjacent to the orthodontic brackets are difficult areas for plaque removal, the use of ultrasonic brushes could be a valid option in the attempt to reduce the incidence of caries lesions in the buccal surfaces in patients undergoing orthodontic therapy.

Other studies in the literature present varied results. Thienpont et al[12] compared two electric and two manual toothbrushes in patients with fixed orthodontic appliances to show no significant differences among the four brushes for plaque scores. Moritis et al[13] and Platt et al,[14] on the other hand, found that sonic toothbrushes removed significantly more plaque than manual brushes.

The absence of attachment loss in all patients suggests that, within the study parameters, the GI is the most useful measure of gingival health. No statistical differences were identified for this parameter. Although a statistical reduction in PI of the vestibular surfaces was found in this study, no difference in GI was observed. The initial low values of the PI may have contributed to a lack of an observable statistical difference in this inflammatory parameter. Lower plaque levels have been described as having the potential to offset any beneficial effects that power brushes may confer on those with poorer oral hygiene.[11] Tritten and Armitage,[15] when comparing a manual and a sonic toothbrush (Sonicare, Optiva Corp, Bellevue, Wash), found that both types were equally effective in reducing gingival inflammation. Our study also corroborates the results of Vandana and Penumatsa,[16] who compared an ultrasonic toothbrush to a manual one in relation to oral hygiene conditions and did not find a significant difference between the two.

Because these study subjects were humans, the influence of the ''Hawthorne effect'' must be considered. Because of the attention focused on plaque and gingivitis, spurious and uncontrolled changes may take place in the levels of oral hygiene.[17] Crossover studies tend to compensate for this effect. Moreover, an effort was made to control as many study variables as possible, including motivation as well as the duration and frequency of toothbrushing.[18]

PD was not significantly reduced. All patients presented gingivitis, and an eventual reduction in PD would result from a diminishing edema with improved gingival hygiene. In this way, the lack of change in inflammation which accounted for no change in GI was also responsible for the find of no change in PD.

Although there were no differences in the GI or PD, the reduction of plaque on vestibular surfaces suggests that new studies need to be made with patients having more serious inflammation to better define the benefits of the brush in question. Results also show that the type of brush is not so important for patients with a good program of plaque control. However, those who are less careful may benefit from ultrasonic brushes.

Our study results differ in part from those of Terezhalmy et al[5] and Zimmer et al.[19] The former found, in a 6-month period, a statistically significant decrease in overnight plaque formation, improved removal, and reduced gingivitis in the group using ultrasonic brushes. In the latter, the ultrasonic toothbrush might be more efficient than the manual toothbrush in removing plaque and preventing gingivitis in patients without se-

vere periodontal disease. These authors attributed this improvement to the ultrasonic waves produced by the brush.[20] Theoretically, these waves, transmitted subgingivally, can remove adherent bacterial plaque and disrupt bacterial growth to significantly reduce inflammation.[21]

In this study, the phenomenon appears to have a limited impact on reduction of gingival inflammation. On the other hand, Forgas-Brockmann et al[6] evaluated the effect of an ultrasonic brush (Ultrasonex®) on the reduction of plaque and gingival inflammation compared to a manual brush (Oral B) in a 30-day period. An improvement in gingival inflammation was noted when manual or power brushes were used, with comparable results.

In vitro studies indicate that the dynamic fluid activity generated by sonic toothbrushes is capable of removing bacteria adhering to saliva-coated hydroxyapatite [21] and removing or fragmenting fimbriae from the cell wall of *Actinomyces viscosus*.[22] Studies have established that gram-positive bacteria are less sensitive to acoustic energy than are gram-negative bacteria.[23,24] Notwithstanding this, Robrish et al[23] reported a hierarchy of microbial sensitivity to sonic energy wherein *S mutans* was 600 times more resistant than *Fusobacterium nucleatum*. On the other hand, Adams et al[25] showed in vitro that a sonic toothbrush (Sonicare Elite, Philips Oral Healthcare Inc, Snoqualmie, Wash) reduced the thickness of *S mutans* biofilm.

In our study, counts of *S mutans* observed with ultrasonic and electric brushes both decreased significantly after 1 month, corroborating the results of Adams et al.[25] This implies that the ultrasonic brush, as well as the electric one used, can present better results in the control of caries lesions. There are few in vivo studies comparing brushes using microbiological techniques. Haffajee et al[26] analyzed the presence and quantity of various bacteria, including *S mutans*, in patients with chronic periodontitis using checkerboard DNA-DNA hybridization. They found no differences in levels of *S mutans* among the patients who had used an electric brush for 6 months.

CONCLUSIONS

- This study did not demonstrate that the ultrasonic toothbrush was better in reducing gingival inflammation in adolescent orthodontic patients, but plaque scores were lowered on the buccal surfaces of teeth with orthodontic brackets.
- In addition, the *S mutans* counts were markedly decreased in the electric and ultrasonic groups, which should be related to a reduced risk of oral disease.

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