Original Article

Powered vs Manual Tooth Brushing in Fixed Appliance Patients: A Short Term Randomized Clinical Trial

J. Hickman, BDS, MPhil, MScD, FDS (Orth), MOrtho[a]; D. T. Millett, BDSc, DDS, FDS, MOrth[b]; L. Sander, BDS, PhD[c]; E. Brown, EDH[d]; J. Love, BSc, PhD[e]

Abstract: Sixty-three orthodontic patients wearing upper and lower fixed appliances were randomly assigned to use either a powered toothbrush fitted with a modified orthodontic brush head (Braun Oral-B Plaque Remover 3D) or a manual toothbrush (Reach Compact Medium). A trained hygienist instructed each patient on the proper use of the allocated brush. Measurements of plaque and gingival health were made at baseline, at four weeks, and at eight weeks. Data for each group were analyzed using paired *t*-tests. Patients using the powered toothbrush showed a significant reduction in percentage interdental bleeding scores from baseline to four weeks (−12.7, $P = .003$) and this was still apparent at eight weeks (−8.6, $P = .028$), although there were no statistically significant changes in either plaque or gingivitis scores for this group. Those patients using a manual toothbrush showed a significant reduction in mean plaque score from baseline (four weeks = −0.18, $P = < .001$; eight weeks = −0.12, $P = .016$), but gingivitis scores were only reduced significantly at four weeks. In this group, interdental bleeding scores reduced significantly at four weeks ($P = .028$), but were not significantly different from baseline at eight weeks ($P = .0319$). When the two patient groups were compared using two sample *t*-tests, there were no significant differences in any of the parameters measured at any time point in the study. Over an eight-week period, there were no measurable differences between the powered toothbrush with modified orthodontic brush head and a manual toothbrush with respect to mean change in plaque, gingivitis, or interdental bleeding scores when used by patients wearing fixed appliances. (*Angle Orthod* 2002;72:135–140.)

Key Words: Powered tooth brushing; Fixed appliances; Randomized clinical trial

INTRODUCTION

Good plaque control is an important factor in the maintenance of dental health during fixed appliance therapy.[1–3] Brackets, archwires, and other appliance components are both a focus for plaque accumulation and an obstruction to plaque removal, thereby promoting gingivitis.[4] Plaque also harbors cariogenic bacteria potentially capable of hard tissue damage, especially at the bracket margins.[2,3] While mouth rinses may aid to reduce plaque formation[1,5] and mechanical cleaning of tooth surfaces can be accomplished in many forms,[6–8] regular tooth brushing is advised routinely as the means of preventing gingival and dental disease during orthodontic appliance therapy.

In pursuit of enhanced plaque control, manual toothbrushes have been designed specifically for use by orthodontic patients but have not been deemed superior to a conventional brush in reducing gingivitis.[9,10] Rotary and counter rotational electric brushes, however, have generally demonstrated greater plaque removing capabilities compared to various types of manual toothbrushes in orthodontic patients.[7,11–17] Only one study has shown plaque removal to be superior with a manual brush.[15]

Electric toothbrushes using a normal brush head or a brush designed specifically for use by orthodontic patients has also been shown to be as effective as a manual brush in removing plaque.[16–18] Despite reduced plaque scores in such power brush trials, concomitant improvements in the gingival health of fixed appliance patients are not as convincing. Only one

[a] Consultant Orthodontist, Orthodontic Department, Glan Clwyd Hospital, Conwy and Denbighshire NHS Trust, Denbighshire, North Wales, UK.

[b] Senior Lecturer and Honorary Consultant in Orthodontics, Orthodontic Unit, Glasgow Dental Hospital and School, North Glasgow University Hospitals NHS Trust, Glasgow, UK.

[c] Periodontologist, Dental Auxiliary Division, Royal Dental College, University of Aarhus, Denmark.

[d] Staff Hygienist, Orthodontic Unit, Glasgow Dental Hospital and School, North Glasgow University Hospitals NHS Trust, Glasgow, UK.

[e] Administrative Statistician, Robertson Center for Biostatistics, University of Glasgow, UK.

Corresponding author: Dr D.T. Millett, Unit of Orthodontics, Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow G2 3JZ, UK.
(e-mail: d.t.millett@dental.gla.ac.uk).

Accepted: October 2001. Submitted: May 2001.

TABLE 1. Inclusion and Exclusion Criteria for the Trial Subjects

Inclusion Criteria	Exclusion Criteria
Good general health	Medical contra-indications including those requiring antibiotic cover
Aged between 10 and 20 years	Immunosuppressant drugs
Wearing upper and lower pre-adjusted edgewise fixed appliances	Poor manual dexterity
Brush at least once per day	Poor compliance
Willing and able to comply with trial regime	Poor periodontal health including presence of supragingival calculus, subgingival calculus, or periodontal pocketing
Dentally fit	Active caries
Gingival bleeding on at least 20% of sites	Oral prophylaxis in previous 4 weeks
	Use of antibiotics or antibacterial mouth rinses during the trial
	Current use of a powered toothbrush

long-term study[7] (>18 months) has reported a significantly sustained reduction in levels of gingivitis in the electric toothbrush group compared to the manual toothbrush group. A more recent short-term study[16] showed no change in the gingival index over eight weeks with either brush type, but orthodontic patients using the power brush with an orthodontic head demonstrated significantly reduced interproximal bleeding compared to baseline.

Recent design modifications to the Braun Oral-B Plaque Remover (D5) have led to the production of the Braun Oral-B Plaque Remover 3D, which can be fitted with a dedicated orthodontic head. Its potential benefits, however, have not been evaluated.

The aim of the present study was to compare the efficacy of the Braun Oral B Plaque Remover 3D, fitted with a specially developed orthodontic appliance brush head and a manual toothbrush (Reach) in controlling plaque and gingivitis in patients with fixed appliances over an eight-week period. The null hypothesis tested was that there was no difference in mean plaque, mean gingivitis, and mean percentage of interdental bleeding scores between subjects using either toothbrush.

MATERIALS AND METHODS

Once approval by the Local Ethical Committee had been granted, patients undergoing treatment with both upper and lower fixed appliances who fulfilled the inclusion and exclusion criteria listed in Table 1 were invited to participate in the study. Written informed consent was obtained from each patient or their guardian and subjects were free to withdraw at any time during the study.

Baseline measurements of plaque and gingival health were recorded for each volunteer by the trial researcher who had been calibrated in the use of the oral hygiene and periodontal indices adopted. Sixty-three subjects with upper and lower fixed appliances were recruited. These patients were randomly assigned to the test (powered tooth brush with orthodontic designed brush head; Braun Oral-B Plaque Remover D5, Braun AG, Germany) or to the control group (manual toothbrush; Reach Compact Head Medium, Johnson and Johnson, Maidenhead, UK). Groups were stratified according to age (under 15 years and 15 years or older), sex, and baseline gingival health (less than 20% of sites with gingival bleeding or more than 20% of sites with gingival bleeding). The trial coordinator who opened a sealed envelope, prepared by the trial statistician, containing the group allocation, undertook randomization. The trial researcher was blinded to the group allocation throughout the trial period.

After patients were assigned to the trial groups, an experienced hygienist gave formal oral hygiene instruction to each patient for the allocated brush, first demonstrating on a set of plastic models of the dental arches fitted with upper and lower fixed appliances. Each subject's brushing competency and understanding was checked and no further tooth brushing instruction was given throughout the trial. Subjects were instructed to brush for a timed two-minute period, after breakfast and before retiring at night, using the allocated brush. The use of an interspace brush was not permitted during the study. Patients assigned to use the manual toothbrush were provided with a digital countdown timer (Whatman International Ltd, Maidstone, UK); the powered toothbrush had an integral two-minute timer. Written instructions and a tooth-brushing diary were also issued, the latter to be completed on a daily basis in an effort to promote compliance.

Each individual was issued a fluoride-containing toothpaste (Colgate Great Regular Flavor, Colgate-Palmolive Ltd, Guildford, UK) free of antiplaque or anticalculus agents. All subjects were also supplied with a fluoride mouth rinse (Colgate Fluorigard, Colgate-Palmolive Ltd, Guildford, UK) and asked to rinse with 10 mL once daily throughout the trial. Use of other dentifrices or mouth rinses was not permitted during the study. At four-week recall, each participant was issued a new brush or brush head, toothpaste, mouthwash, and a tooth-brushing diary, and was also questioned about soft or hard tissue trauma resulting from brushing. All participants were offered the alternative to the allocated brush at the end of the trial.

The examinations at baseline, four weeks, and eight weeks were carried out at the same time of day to minimize diurnal variations. Participants had brushed their teeth after breakfast as normal. Recordings were made adopting the following sequence—orthodontic modification of the plaque index, gingival index, mouth rinse with water, Eastman interdental bleeding index, and assessment of tissue trauma. Following placement of a self-retaining cheek retractor and cotton wool rolls, the teeth were dried with compressed air and plaque scores recorded for four zones (incisal, distal, mesial, and gingival to the bracket or band) on the labial and buccal aspects of the teeth using the ortho-

dontic modification[19] of the Silness and Löe plaque index.[20] This modified index has demonstrated sensitivity in discrimination between plaque levels in subjects with fixed orthodontic appliances.[19] A Community Periodontal Index of Treatment Needs (CPITN) probe,[21] angled at 45°, was moved around the cervical aspect of each tooth just inside the gingival crevice to record the gingival index[22,23] one quadrant at a time. All traces of gingival bleeding were removed by rinsing or by a gentle stream of air and water before recording the Eastman Interdental Bleeding Index.[24] From the buccal aspect, a wooden interdental stick (Interdental Woodsticks, Oral-B laboratories, Aylesbury, UK) was inserted four times between the teeth, depressing the interdental papilla by 1 to 2 mm. After 15 seconds, the presence or absence of interdental bleeding was noted. The Eastman Interdental Bleeding Index was calculated from the number of bleeding sites as a percentage of the total sites assessed.

Power and sample size considerations

The study sample size had a power of 80% to detect, at a statistical significance level of 5%, differences between the study groups with respect to changes from visit 1 to visit 3 in either bleeding, gingivitis, or plaque of the order 0.86 standard deviations (incorporating Bonferroni correction to allow for the analysis of three outcome parameters). For the current study, this would translate to being able to detect a 13% change from baseline for gingivitis, or approximately a 40% change from baseline for plaque or bleeding (assuming no change in the manual toothbrush group).

Use of summary measures

As multiple measurements were recorded for each parameter for each individual, summary measures were produced to facilitate analyses. Matthews et al[25] describe this approach to the analysis of repeated measures data in detail. For plaque, as not all teeth had the same number of sites recorded, the mean of the within-tooth averages was calculated for a given subject. For gingivitis scores, the mean score was calculated over all available sites. The percentage of sites with bleeding was calculated.

To adjust for any imbalances in baseline age, sex, and gingival health, General Linear Modeling was undertaken. The mean and standard deviation for each of the three parameters recorded (plaque, gingivitis, and interdental bleeding) was calculated for each time point. Analyses looking for changes within the individual groups were carried out using paired *t*-tests. Comparisons of the two study groups were made using two-sample *t*-tests.

RESULTS

At baseline (visit 1), 33 subjects (15 boys and 18 girls) were allocated the powered brush and 30 subjects (13 boys and 17 girls) were allocated the manual brush. The mean ages of subjects in the powered brush group was 14.9 ± 1.4 years and in the manual brush group 15.4 ± 2.1 years. Mean percentage gingival bleeding at baseline for those allocated the powered or the manual brush was 28.3 ± 11.5 or 29.4 ± 14.7, respectively. Thus, as expected, due to the stratification process the groups were well balanced with respect to sex, age, and gingival health.

TABLE 2. Mean (SD) per Visit of Plaque, Gingivitis and Percent of Bleeding for Powered and Manual Toothbrushes

	Powered Brush Mean (SD)	Manual Brush Mean (SD)
Plaque		
Visit 1	0.55 (0.26)	0.58 (0.35)
Visit 2	0.47 (0.23)	0.40 (0.23)
Visit 3	0.46 (0.24)	0.46 (0.26)
Gingivitis		
Visit 1	1.17 (0.24)	1.18 (0.28)
Visit 2	1.12 (0.19)	1.09 (0.23)
Visit 3	1.12 (0.18)	1.12 (0.23)
Bleeding (%)		
Visit 1	53.0 (22.3)	47.3 (19.3)
Visit 2	39.4 (20.1)	40.9 (19.4)
Visit 3	43.4 (20.6)	44.0 (20.1)

One subject chose to withdraw from the study and two others were withdrawn, one due to failed compliance and the other because of difficulties with attendance within the recording period. Sixty subjects completed the trial. These comprised 31 subjects (14 boys and 17 girls) who used the powered brush and 29 subjects (12 boys and 17 girls) who used the manual brush. There were no reports or observations of damage to the oral tissues from either toothbrush over the duration of the trial. Subjects allocated the powered brush reported favorably regarding its performance, but objective assessment of patient satisfaction with this product was not undertaken. For both study groups, most reduction in the three parameters assessed was seen between visits 1 and 2, with little reduction (an increase in some cases) apparent between visits 2 and 3 (Table 2).

Within group comparisons (Table 3)

Plaque. For the powered toothbrush group, there were no statistically significant differences observed, either from baseline (visit 1) to visit 2 or visit 3 ($P = .131$ and $P = .145$, respectively), or between visit 2 and visit 3. For the manual toothbrush group, there was a significant reduction in plaque from baseline to visit 2 ($P < .001$) and the significant improvement was still apparent at visit 3 ($P = .016$).

Gingivitis. For the powered toothbrush group, no statistically significant differences were found either from visit 1 to visit 2 or visit 3 ($P = .096$ and $P = .223$, respectively) or from visit 2 to visit 3 ($P = .947$). For the manual tooth-

TABLE 3. Within-Group Comparisons of Mean (SD) Plaque, Gingivitis, and Percent of Bleeding for Powered and Manual Brushes With Associated *P* Values

	Powered Brush		Manual Brush	
	Mean (SD)	*P*-value	Mean (SD)	*P*-value
Plaque				
Visit 2–Visit 1	−0.07 (0.25)	.131	−0.18 (0.25)	<.001
Visit 3–Visit 1	−0.07 (0.27)	.145	−0.12 (0.26)	.016
Visit 3–Visit 2	−0.01 (0.14)	.585	0.05 (0.18)	.126
Gingivitis				
Visit 2–Visit 1	−0.04 (0.14)	.096	−0.09 (0.15)	.004
Visit 3–Visit 1	−0.04 (0.17)	.223	−0.06 (0.18)	.096
Visit 3–Visit 2	0.00 (0.11)	.947	0.03 (0.11)	.145
Bleeding (%)				
Visit 2–Visit 1	−12.7 (21.8)	.003	−6.8 (15.7)	.028
Visit 3–Visit 1	−8.6 (20.9)	.028	−3.6 (19.0)	.319
Visit 3–Visit 2	3.8 (18.6)	.270	3.2 (14.2)	.238

TABLE 4. Between Group Comparisons for Mean Differences in Plaque, Gingivitis and Percent of Bleeding for Powered and Manual Brushes With Associated *P* Values

	P-value for Simple Analysis of Changes	*P*-value Adjusting for Sex, Age, and Baseline Gingival Health
Plaque		
Visit 2–Visit 1	.090	.096
Visit 3–Visit 1	.448	.450
Visit 3–Visit 2	.114	.151
Gingivitis		
Visit 2–Visit 1	.219	.367
Visit 3–Visit 1	.676	.816
Visit 3–Visit 2	.311	.212
Bleeding (%)		
Visit 2–Visit 1	.235	.234
Visit 3–Visit 1	.333	.390
Visit 3–Visit 2	.893	.771

brush group, although there was a significant reduction in gingivitis from visit 1 to visit 2 ($P = .004$), by visit 3 the change from baseline was no longer significant ($P = .096$).

Bleeding. For the powered toothbrush group, there was a significant reduction in bleeding from visit 1 to visit 2 ($P = .003$) and this significant improvement from baseline was still apparent by visit 3 ($P = .028$). A significant, but less marked, reduction in bleeding also occurred in the manual toothbrush group from baseline to visit 2 ($P = .028$) but by visit 3 the change from baseline was no longer significant ($P = .0319$).

Between group comparisons (Table 4)

For all between visit comparisons, no statistically significant differences were detected between the study groups for any of the parameters assessed, irrespective of whether analyses were conducted based on simple changes or incorporated correction for baseline characteristics.

DISCUSSION

This randomized controlled study gives important information on the efficacy of a powered toothbrush with a dedicated orthodontic head, compared to a manual toothbrush on the oral health of orthodontic patients undergoing fixed appliance therapy in a hospital clinic. A crossover design, enabling each brush to be tested in each subject, has been employed in many comparative tooth-brushing studies in orthodontic patients,[12–15,17] but a parallel group design has also been used.[16] If the latter approach is used, it can be useful to incorporate stratification into the randomization process to ensure relative balance with respect to important prognostic factors at baseline, thus lessening the likelihood that the final study results will be confounded by baseline differences between the study groups.

Observations of plaque removal in tooth brushing trials in orthodontic patients vary from one day to two months[16,17] with one notable exception of 18 months.[7] Those which incorporate measurements of gingival changes usually run for a minimum of four weeks as over this period clinically meaningful alterations in plaque and gingival bleeding have been recorded in nonorthodontic groups.[26–28] The eight-week duration of the present study falls in line with the recommendation in the ADA acceptance program guidelines for toothbrushes that the trial should extend over a minimum of 30 days.[26,29] While long-term dental hygiene practices at home are more likely to be reflected in trials extending over several months, compliance with the trial regime can become problematic, thereby providing an imprecise assessment of the efficacy and usefulness of a toothbrush.[26]

Tooth brushing duration has also varied between studies. To remove the potential bias that this variable would introduce in the trial reported here, subjects allocated the manual toothbrush were issued a digital timer and instructed to brush twice daily for a timed two minutes. This procedure has been used in other studies.[15–17] Subjects allocated the powered toothbrush were given identical instructions and the brush has an integral two minute timer, therefore, tooth brushing duration should have been standardized between groups. Clerehugh et al[16] used a similar duration although other investigators have employed a two-minute tooth brushing time only for subjects allocated the manual toothbrush and three minutes for the powered brush.[17]

Indices used to score plaque do not account adequately for the particular plaque retention problems posed by fixed appliance components. A modification[19] of the plaque index,[20] developed specifically for use in subjects with fixed orthodontic appliances and which has objective sensitivity in this regard,[19] was used in the present study. It has been employed previously in a practice-based trial comparing a

powered and a manual toothbrush in fixed appliance orthodontic patients.[16] In the study reported here, plaque was only assessed on the buccal surfaces of teeth that were bonded or banded. The lingual surfaces, which other reports have noted were improved considerably in nonorthodontic subjects by use of a powered brush,[30] were not included in analyses. Although this approach has been used in another similar trial,[16] it is possible that it has increased the risk of making a Type II error through exclusion of regions where the difference between the groups may be largest.

At baseline, mean plaque scores were just over 0.50 in each group, demonstrating much better oral hygiene than those subjects entered in a similar trial.[16] This could account for the modest improvements in the various parameters seen during the current trial. Lower plaque levels have been described as having the potential to 'neutralize' any beneficial effects that power brushes confer on those with poorer oral hygiene.[13]

Over an eight-week period, the manual tooth brushing group exhibited a significant reduction in mean plaque scores, which may be due to involvement in the trial, the formal hygiene instruction given at the time of toothbrush allocation, and the use of a timing device to remind participants of the duration of brushing. Although subjects allocated the powered toothbrush were given specific instructions with regard to tooth brushing, no significant reduction in mean plaque scores was observed over the trial period. This may be due in part to the subjects having to adapt to a new brush and brushing technique.

Two indices were used to assess the impact of plaque on gingival health. Color, swelling, and bleeding were assessed by the gingival index.[22,23] Mean gingivitis scores were only reduced significantly at four weeks in the manual toothbrushing group, despite a significant reduction in mean plaque score being recorded at eight weeks. This apparent conflict between plaque and gingivitis scores has been reported previously.[31] No significant reduction, however, was observed in mean gingivitis scores for the powered toothbrush group from baseline to the conclusion of the trial.

The usefulness of each brush in the interdental area was also assessed using the Eastman Interdental Bleeding Index.[24] The value of this index in assessment of the efficacy of interdental hygiene measures has been emphasized.[32] Subjects allocated the powered toothbrush exhibited a statistically significant reduction in mean percentage of interdental bleeding scores over the trial period, confirming the findings of Clerehugh et al.[16] This most likely reflects the ability of the specific small head design to access interdental areas, but also may be due to acoustic microstreaming.[33]

When the toothbrush groups were compared, there were no statistically significant differences observed for any of the parameters assessed at any of the time points of the study. This confirms the findings of studies[16,17] where other types of orthodontically dedicated powered toothbrushes have been compared to manual toothbrushes in fixed appliance patients.

CONCLUSIONS

A powered toothbrush with a dedicated orthodontic head (Braun Oral B 3D) was as effective as a manual toothbrush (Reach) at cleaning around fixed orthodontic appliances.

For subjects using a powered toothbrush with an orthodontic head, the most marked improvement in oral health was in interdental bleeding.

ACKNOWLEDGMENTS

We would like to thank Dr P. Warren, Braun Oral B, Kronberg, Germany for his helpful advice throughout this trial. Braun Oral B, Germany, supported the study.

REFERENCES

1. Zachrisson BU. Cause and prevention of injuries to teeth and supporting structures during orthodontic treatment. *Am J Orthod.* 1976;69:285–300.
2. Mitchell L. Decalcification during orthodontic treatment with fixed appliances: an overview. *Br J Orthod.* 1992;19:199–205.
3. Atack NE, Sandy JR, Addy M. Periodontal and microbiological changes associated with the placement of orthodontic appliances. A review. *J Periodontol.* 1996;67:78–85.
4. Zachrisson S, Zachrisson BU. Gingival condition associated with orthodontic treatment. *Angle Orthod.* 1972;42:26–34.
5. Millar RA, McIver JE, Gunsolley JC. Effects of sanguinaria extract on plaque retention and gingival health. *J Clin Orthod.* 1988; 22:304–307.
6. Huber SJ, Vernino AR, Nanda RS. Professional prophylaxis and its effect on the periodontium of full-banded orthodontic patients. *Am J Orthod Dentofacial Orthop.* 1987;91:321–327.
7. Boyd RL, Murray P, Robertson PB. Effect of rotary electric toothbrush versus manual toothbrush on periodontal status during orthodontic treatment. *Am J Orthod Dentofacial Orthop.* 1989;96: 342–347.
8. Yeung SCM, Howell S, Fahey P. Oral hygiene program for orthodontic patients. *Am J Orthod Dentofacial Orthop.* 1989;96: 208–213.
9. Williams P, Fenwick A, Schou L, Adams W. A clinical trial of an orthodontic toothbrush. *Eur J Orthod.* 1987;9:295–304.
10. Kilicoglu H, Yildirim M, Polater H. Comparison of the effectiveness of two types of toothbrushes on the oral hygiene of patients undergoing orthodontic treatment with fixed appliances. *Am J Orthod Dentofacial Orthop.* 1997;111:591–594.
11. Long DE, Killoy WJ. Evaluation of the effectiveness of the INTERPLAK home plaque removal instrument on plaque removal and orthodontic patients. *Compend Contin Educ Dent.* 1985; (suppl 6):156–160.
12. Trombelli L, Scabbia A, Griselli A, Zangari F, Calura G. Clinical evaluation of plaque removal by counterrotational electric toothbrush in orthodontic patients. *Quintessence Int.* 1995;26:199–202.
13. Heintze SD, Jost-Brinkmann PG, Loundos J. Effectiveness of three different types of electric toothbrushes compared with a manual technique in orthodontic patients. *Am J Orthod Dentofacial Orthop.* 1996;110:630–638.
14. Wilcoxon DB, Ackerman RJ Jr, Killoy WJ, Love JW, Sakumura JS, Tira DE. The effectiveness of a counterrotational-action power

toothbrush on plaque control in orthodontic patients. *Am J Orthod Dentofacial Orthop.* 1991;99:7–14.
15. Trimpeneers LM, Wijgaerts IA, Grognard NA, Dermaut LR, Adriaens PA. Effect of electric toothbrushes versus manual toothbrushes on removal of plaque and periodontal status during orthodontic treatment. *Am J Orthod Dentofacial Orthop.* 1997;111: 492–497.
16. Clerehugh V, Williams P, Shaw WC, Worthington HV, Warren P. A practice-based randomised controlled trial of the efficacy of an electric and a manual toothbrush on gingival health in patients with fixed orthodontic appliances. *J Dent.* 1998;26:633–639.
17. Heasman P, Wilson Z, Macgregor I, Kelly P. Comparative study of electric and manual toothbrushes in patients with fixed orthodontic appliances. *Am J Orthod Dentofacial Orthop.* 1998;114: 45–49.
18. Jackson CL. Comparison between electric toothbrushing and manual toothbrushing, with and without oral irrigation, for oral hygiene of orthodontic patients. *Am J Orthod Dentofacial Orthop.* 1991;99:15–20.
19. Williams P, Clerehugh V, Shaw WC. A comparison of a photographic index with a modified clinical plaque index for use with orthodontic fixed appliance patients [abstract 276]. *J Dent Res.* 1991;70:703.
20. Silness J, Löe H. Periodontal disease in pregnancy II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand.* 1964;22:121–135.
21. Ainamo J, Barmes D, Beagrie G, Cutress T, Martin J, Sardo-Infirri J. Development of the World Health Organization (WHO) community periodontal index of treatment needs (CPITN). *Int Dent J.* 1982;32:281–291.
22. Löe H, Silness J. Periodontal disease in pregnancy I. Prevalence and severity. *Acta Odontol Scand.* 1963;21:533–551.
23. Löe H. The gingival index, the plaque index and the retention index systems. *J Periodontol.* 1967;38:610–616.
24. Caton JG, Polson AM. The interdental bleeding index: a simplified procedure for monitoring gingival health. *Compend Contin Educ Dent.* 1985;6:88, 90–92.
25. Matthews JN, Altman DG, Campbell MJ, Royston P. Analysis of serial measurements in medical research. *BMJ.* 1990;300:230–235.
26. Heasman PA, McCracken GI. Powered toothbrushes: a review of clinical trials. *J Clin Periodontol.* 1999;26:407–420.
27. Baab DA, Johnson RH. The effect of a new electric toothbrush on supragingival plaque and gingivitis. *J Periodontol.* 1989;60: 336–341.
28. Khocht A, Spindel L, Person P. A comparative clinical study of the safety and efficacy of three toothbrushes. *J Periodontol.* 1992; 63:603–610.
29. Council on Scientific Affairs, American Dental Association. *Proposed revision to American Dental Association acceptance program guidelines for toothbrushes.* Chicago, Ill: American Dental Association; 1995.
30. Warren PR, Chater B. The role of the electric toothbrush in the control of plaque and gingivitis: a review of 5 years clinical experience with the Braun Oral-B Plaque Remover (D7). *Am J Dent.* 1996;9 Spec No:5–11.
31. Spindel LM, Chauncey HH, Person P. Plaque reduction unaccompanied by gingivitis reduction. *J Periodontol.* 1986;57:551–554.
32. Kleisner J, Imfeld T. Evaluation of the efficacy of interdental cleaning devices. How to design a clinical study. *J Clin Periodontol.* 1993;20:707–713.
33. Walmsley AD. The electric toothbrush: a review. *Br Dent J.* 1997; 182:209–218.