The regular and effective removal of plaque from all surfaces of teeth, both above and below the gingival margin, is essential for the prevention of gingival and periodontal disease. Effective removal of plaque is compromised significantly when fixed orthodontic appliances are worn and the accumulation of plaque, and the development of gingivitis and gingival overgrowth are well-recognized problems. In some cases, a simple gingivitis may progress to destructive periodontitis although this does not appear to be a significant problem during orthodontic therapy in adolescents.

In an attempt to facilitate plaque control in orthodontic patients, specifically designed manual and electric toothbrushes have been developed. Manual brushes with V-shaped longitudinal grooves in the brushing surface are intended to improve brushing around brackets and arch wires, although their effectiveness in reducing gingivitis compared with conventional brushes is questionable. Electric toothbrushes can improve plaque control without causing damage to the components of the orthodontic appliance. For example, rotary and counter-rotational brushes have been shown to be particularly effective in plaque removal and reducing gingivitis in orthodontic patients.

Improvements in the design of electric toothbrushes are constantly being sought and one recently marketed product, the Dental Logic HP550 (Philips DAP, Groningen, Netherlands), has incorporated several practical features that may be of value in improving plaque control around fixed appliances. These features include brush head movements in two directions and at two speeds simultaneously, and a unique, soft pressure gum protection system that regulates the amount of force (maximum 300 gm) that is applied to the teeth and gingiva. The brush (or brushhead) was
not, however, designed specifically for use by orthodontic patients.

The aim of this study was to evaluate the efficacy of the HP550 Dental Logic brush, a manual orthodontic toothbrush, and a powered orthodontic toothbrush in decreasing plaque accumulation and gingival inflammation in a cohort of children undergoing orthodontic treatment.

MATERIAL AND METHODS

This is a three-period, three-treatment, balanced, Latin square-type, single-blind cross-over clinical trial of three toothbrushes with children undergoing fixed orthodontic treatment. Ethical approval for the protocol was granted by the Joint Ethics Committee of the Newcastle and North Tyneside Health Authorities.

Sixty patients (males and females) between the ages of 10 and 16 years were recruited from the Department of Orthodontics at Newcastle Dental Hospital. All patients had started orthodontic treatment within the previous 12 months and had at least 12 brackets (or bands) on teeth in each arch. Written informed consent was given by the parent or legal guardian.

Patients were excluded if they had

1. previously used an electric toothbrush or a manual orthodontic brush
2. a history of early onset periodontal disease,
3. a mental handicap,
4. a physical handicap that restricted free movement of hands or fingers
5. received oral hygiene instruction from a dental professional within the previous 6 months

The patients were examined by a clinician (screening visit) for suitability and an information sheet was given to the parent or guardian. Enrollment for the baseline visit followed the provision of written consent. At baseline, 2 weeks after screening, each patient was allocated at random, to one of three groups (n = 20) each with a sequenced three-period regimen of toothbrushing; each period of 4 weeks duration was associated with the use of one toothbrush. The trial toothbrushes were (1) Oral B manual orthodontic brush, (2) Braun electric toothbrush (D7, Braun AG, Germany) with orthodontic head ODS-1, (3) HP550 electric toothbrush with head HP5924. The sequence of treatments for each numerically balanced allocation of patients was 1-2-3, 2-1-3, 3-2-1. A standard, fluoride-containing dentifrice was given to all patients for use throughout the trial.

Design

At baseline an examination of the gingiva was undertaken for visible signs of abrasion, ulceration, swelling, or gingival recession. Plaque was scored with the Visible Plaque Index (VPI) at six sites around each tooth (mesial, buccal, lingual, distal) with the Gingival Bleeding Index (GBI). Bleeding was provoked by probing each site with a TPS (pressure sensitive) probe (Vivadent, Schaan, Liechtenstein). Patients were next seen (visit 1) 2 weeks after the baseline visit. Clinical scores and the oral examination were repeated. The fixed appliances were adjusted if required; to maintain the blind nature of the design and to prevent bias, instructions in the use of all three brushes were given (Z.W.). For the electric toothbrushes, the manufacturer’s instructions were read through with the patient; the purpose and design of the manual toothbrush were also discussed. A combination of the Bass and Charters techniques was taught diagrammatically with use of the manual toothbrush so that plaque was removed from the gingival sulcus and the gingival facing surface of brackets. The suggested brushing time for the electric toothbrushes was at least 3 minutes, twice daily. A minimum of 2 minutes brushing time (twice daily) was recommended for the manual toothbrush. The first brush in the sequence was then given to each patient and by a different researcher (P.H.) from the one who had given the instructions in toothbrushing. Appointment times for each visit were scheduled for between 2 and 3 hours after an episode of toothbrushing.

At the conclusion of each 4-week brushing period, oral examination and clinical scores were repeated, and the orthodontic appliances adjusted where necessary. A dental prophylaxis given before the sequence was repeated for the second and third brushes. The clinical indexes were measured, and the instructions in using all three toothbrushes were repeated. On completion of the trial all patients continued with their orthodontic treatment.

Repeatability

Two research dental hygienists carried out the examinations and clinical scoring. A prestudy calibration (repeatability) exercise was undertaken scoring full mouth sites on each of five subjects (10 to 15 years old) who were not involved in the main study. The mean intraexaminer exact agreements for the examiners were VPI, 88% and 84%; GBI, 89% and 92%. The mean interexaminer exact agreements were VPI, 83%; GBI, 88%.

Statistical analysis

Statistical analysis was undertaken with analysis of variance with treatments for subject, period, and toothbrushing regimen. The VPI (primary outcome variable for toothbrush efficacy) was analyzed on a site-specific basis: buccal smooth (Bs) and interproximal (Bi) surfaces, lingual smooth (Ls) and interproximal (Li) surfaces.

Good clinical practice

The study conformed to guidelines for Good Clinical Practice. The study site and procedure were audited by an independent assessor on three occasions, and no breach of
Results

All subjects completed the study. The cohort comprised 21 males and 39 females with the mean age of 13.6 (± 1.2) years. Mean site specific plaque indexes and gingival indexes at baseline and visit 1 are shown in Table I. Plaque indexes at all sites at visit 1 were consistently and significantly lower than those at baseline (at \( p = 0.05; t \) test). There were, however, no differences in bleeding scores between baseline and visit 1.

Tables II and III show the VPI at smooth and interproximal sites respectively for the buccal and lingual tooth surfaces. Data are presented for each brush at the end of each brushing period (of 4 weeks), as well as for all brushes and for all periods. Table IV shows the full mouth gingival bleeding scores after the use of each brush at the end of each brushing period. The data for all brushes and all periods are also shown. In summary, there were no differences between the brushes in their efficacy in reducing plaque scores at buccal (smooth/interproximal) or lingual (smooth/interproximal) sites. Similarly, there were no differences between the brushes in their effect on gingival bleeding scores. There was no evidence of gingival trauma in any subject at any time during the study.

**DISCUSSION**

The study was designed to test the plaque removing effects of a manual orthodontic toothbrush and two electric toothbrushes in a cohort of patients with fixed orthodontic appliances. The manual brush has a longitudinal groove in the brushing surface to facilitate brushing around brackets and arch wires. The Braun brush head OD5-1 is also designed to improve cleaning around fixed appliances and the brush moves with a rotating/oscillating motion. The brush head on the Philips HP550 moves simultaneously in two directions and at two speeds. This brush is not specifically recommended for patients with fixed orthodontic appliances but the brush head movements may be considered appropriate for cleaning the gingival crevice and interproximally, beneath components of an appliance.

The Braun Plaque Control electric toothbrush (models D3, D5, and D7) has repeatedly been shown to remove more plaque than manual brushes in non-orthodontic patients in both cross-over and parallel studies. The more specific question regarding the value of electric brushes for orthodontic patients has received less attention, although a number of different designs have been tested and the brushes found to be efficacious when compared to manual brushes.17-21

Our cross-over design enabled each brush to be tested on each subject. This eliminated any potential for intersubject variation to result from different numbers of brackets or types of components in the appliance. The inclusion of three ‘groups’ with different sequences of brushing was designed to compensate for the absence of a ‘wash-out’ period. It was considered extremely unlikely, however, that the use of one brush would influence the use of any other because of the different techniques required for each toothbrush. One of the main variables in toothbrushing studies reported in the literature is the period of observation. A time interval of 4 weeks has been shown to be sufficient to observe meaningful changes in plaque and bleeding.28-30 Studies of longer duration are more likely to allow observations that reflect an individual’s long-term dental hygiene practices at home, but a more precise evaluation of the efficacy and potential of a toothbrush may be less apparent as the compliance of subjects becomes an additional variable. As the efficacy of the HP550 had, as far as we are aware, not been determined in controlled clinical studies, we opted for the shorter period of observation.

Another variable between studies is the time spent brushing. We recommended that each subject use the manual brush for 2 minutes, twice a day. It has previously been shown that brushing for 2 minutes with an electric brush will reduce plaque scores by 75% to 88% depending on the brush design.31 As none of the subjects had previously used an electric toothbrush and in view of the potential difficulties in cleaning around fixed ortho-

**Table I. Plaque scores (%) (mean ± SD) at baseline and visit 1**

<table>
<thead>
<tr>
<th>VPI</th>
<th>Baseline</th>
<th>Visit 1</th>
<th>Baseline—Visit 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Buccal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td>53 (±23)</td>
<td>39 (±20)</td>
<td>( p &lt; 0.001 )</td>
</tr>
<tr>
<td>Interproximal</td>
<td>71 (±19)</td>
<td>65 (±18)</td>
<td>( p &lt; 0.02 )</td>
</tr>
<tr>
<td><strong>Lingual</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td>69 (±21)</td>
<td>57 (±21)</td>
<td>( p &lt; 0.01 )</td>
</tr>
<tr>
<td>Interproximal</td>
<td>76 (±16)</td>
<td>68 (±18)</td>
<td>( p &lt; 0.05 )</td>
</tr>
<tr>
<td><strong>GBI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>31 (±19)</td>
<td>26 (±16)</td>
<td>( p &gt; 0.05 )</td>
</tr>
</tbody>
</table>

VPI, Visible Plaque Index.
GBI, Gingival Bleeding Index.
SD, Standard deviation.
Table II. Visible Plaque Index % scores (mean ± SD) at smooth surfaces at the end of each experimental period

<table>
<thead>
<tr>
<th></th>
<th>Buccal</th>
<th>Lingual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 1</td>
<td>Period 2</td>
</tr>
<tr>
<td>Manual brush</td>
<td>39 (± 18)</td>
<td>—</td>
</tr>
<tr>
<td>Braun Electric OD5</td>
<td>39 (± 22)</td>
<td>42 (± 21)</td>
</tr>
<tr>
<td>Philips HP 550</td>
<td>39 (± 18)</td>
<td>32 (± 18)</td>
</tr>
<tr>
<td>All brushes</td>
<td>39 (± 19)</td>
<td>38 (± 21)</td>
</tr>
</tbody>
</table>

SD, Standard deviation.

Table III. Visible Plaque Index % scores (mean ± SD) at interproximal surfaces at the end of each experimental period

<table>
<thead>
<tr>
<th></th>
<th>Buccal</th>
<th>Lingual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period 1</td>
<td>Period 2</td>
</tr>
<tr>
<td>Manual brush</td>
<td>61 (± 14)</td>
<td>—</td>
</tr>
<tr>
<td>Braun Electric OD5</td>
<td>61 (± 20)</td>
<td>59 (± 20)</td>
</tr>
<tr>
<td>Philips HP 550</td>
<td>64 (± 18)</td>
<td>63 (± 18)</td>
</tr>
<tr>
<td>All brushes</td>
<td>62 (± 17)</td>
<td>60 (± 20)</td>
</tr>
</tbody>
</table>

SD, standard deviation.

Table IV. Full mouth Gingival Bleeding Index % scores (mean ± SD) at the end of each experimental period

<table>
<thead>
<tr>
<th></th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
<th>All periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual brush</td>
<td>21 (± 12)</td>
<td>—</td>
<td>14 (± 8)</td>
<td>17 (± 10)</td>
</tr>
<tr>
<td>Braun Electric OD5</td>
<td>20 (± 13)</td>
<td>16 (± 11)</td>
<td>—</td>
<td>17 (± 12)</td>
</tr>
<tr>
<td>Philips HP 550</td>
<td>19 (± 12)</td>
<td>17 (± 10)</td>
<td>18 (± 9)</td>
<td>18 (± 10)</td>
</tr>
<tr>
<td>All brushes</td>
<td>20 (± 12)</td>
<td>16 (± 11)</td>
<td>15 (± 9)</td>
<td>—</td>
</tr>
</tbody>
</table>

SD, Standard deviation.

The results of our study demonstrated equal efficacy in reducing plaque and gingival bleeding scores for the three products tested. No brush demonstrated superiority at either smooth or interproximal surfaces, although the plaque scores at smooth surfaces at baseline and thereafter were consistently lower compared with interproximal sites. The plaque scores for each brush at smooth and interproximal surfaces, regardless of the period and sequence of brushing, were consistently lower than those at baseline but virtually identical to those at visit 1. Indeed, the mean plaque scores at all surfaces at visit 1 were consistently and significantly lower than scores at baseline (*p* < 0.05; Table I). As none of the test brushes was used until visit 1 and no alteration in oral hygiene practices was recommended at baseline, the reduction in plaque scores observed between these visits is attributed to the Hawthorne effect.32 This change in behavior of subjects who anticipate involvement in a clinical trial has been observed previously and may be a source of variability for cross-over designs.33 We believe that this observation alone justifies the inclusion of the pretest period between screening and the first experimental period to allow a short period for Hawthorne stabilization.

There was no significant difference between full mouth gingival bleeding scores at baseline and visit 1; this suggests that the reduction in plaque scores over the same period was clinically insignificant and insufficient to affect resolution of the inflammatory response. This apparent lack of correlation between odontic appliances, we increased the brushing time to 3 minutes when an electric brush was used.

When designing the study, it was considered that the proximity of orthodontic bands and brackets to the gingival margin might complicate scoring of plaque. Plaque was therefore recorded dichotomously using the Visible Plaque Index rather than quantitatively, which is otherwise the preferred method in most longitudinal clinical trials.

Plaque scores at all surfaces at baseline were greater than 50%, and our subjects therefore correspond to those considered to have ‘poor’ oral hygiene in the study of Heintze et al.21 This cross-over study of three electric and one manual brush found that over a 4 week period, the Braun Oral B and Rota-dent (Kusnacht, Switzerland) brushes were more efficacious in reducing full mouth plaque scores when compared with the Interplak (Bausch and Lomb, Germany) and a manual brush. When scores at specific surfaces were analyzed, however, none of the brushes demonstrated superiority.
plaque and gingivitis scores has also been observed by other workers.\textsuperscript{30,34}

**CONCLUSION**

This 4 week, cross-over study demonstrated that the Philips HP550, the dedicated electric Braun D7, and the manual (Oral B) orthodontic brushes were equally effective in removing plaque and reducing gingival inflammation as indicated by bleeding on probing in patients undergoing fixed orthodontic treatment. This suggests that further research is necessary to improve the designs of orthodontic toothbrushes. Clinicians and hygienists should appreciate that dedicated brushes may offer no advantages in cleaning interproximally and in the gingival crevice.

**REFERENCES**
