Comparison of different toothbrushing protocols in poor-toothbrushing orthodontic patients

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SUMMARY The aim of this study was to determine, using a computerized image analysing system, whether the use of a curved-bristle toothbrush (CBT) alone is more effective than two other toothbrushing protocols on dental plaque elimination in poor-toothbrushing orthodontic patients. The labial surfaces of the maxillary canine-to-canine anterior teeth of 30 patients (12 males and 18 females) were individually photographed following dental plaque staining before and 4 weeks after each toothbrushing protocol, with a 1-month washout interval. The toothbrushes used were (1) a CBT, (2) an orthodontic toothbrush (OT), and (3) an OT in combination with interproximal toothbrush (IT) (OT+IT). Total labial surfaces of the anterior teeth and stained plaque areas were measured and gingival indices (GIs) were also recorded.

Repeated measures analysis of variance and Tukey's Honestly Significant Difference multiple range tests showed that the OT+IT produced a statistically significant decrease in the mean plaque percentage both for the total labial (7.2%) and interproximal (17.7%) tooth surfaces, when compared with the other toothbrushing protocols ($P<0.05$). No statistically significant differences were found between the CBT and OT for the amount of bacterial plaque and GI scores ($P>0.05$).

Neither the CBT nor the OT alone was able to remove plaque under the archwires in poor-toothbrushing patients. Therefore, the use of ITs should be mandatory for effective plaque removal in these patients.

Introduction

Effective oral hygiene is especially important for those undergoing orthodontic therapy. Fixed orthodontic appliances can prevent both effective toothbrushing and the mechanical cleaning action of mastication, leading to plaque accumulation. Taking into consideration the long treatment times, emphasis must be placed on routine hygiene for the orthodontic patient, including professional tooth cleaning and home care instructions (Gold, 1975; Clark, 1976; Yeung *et al.*, 1989).

An important part of motivating the orthodontic patient is choosing oral hygiene tools that will best meet the individual's needs. Innovations in this field present numerous alternatives for the clinician (Boyd *et al.*, 1989; Berglund and Small, 1990; Heintze *et al.*, 1996; White, 1996). These include electric toothbrushes (Boyd *et al.*, 1989; Heintze *et al.*, 1996), orthodontic toothbrushes (OTs) with different brush head designs, oral irrigators (York and Dunkin 1967; Hurst and Madonia, 1970), dental flosses, and interproximal toothbrushes (ITs). Numerous studies have evaluated and compared these oral hygiene tools. A recent meta-analysis revealed that powered toothbrushes with a rotation oscillation action reduced plaque and gingivitis more than manual toothbrushing (Robinson *et al.*, 2005). In particular, studies comparing manual with electric toothbrushes have presented conflicting results in orthodontic patients. While some studies suggest that electric toothbrushes are superior to manual toothbrushes (Boyd *et al.*, 1989; Heintze *et al.*, 1996; White, 1996), others

report equal effectiveness in plaque removal (Jackson, 1991; Kilicoğlu *et al.*, 1997; Heasman *et al.*, 1998).

Manual toothbrushes with different head designs are still the focus of interest for both manufacturers and clinicians. Studies in non-orthodontic adults, children, and care-dependent elderly, suggest that curved-bristle toothbrushes (CBTs) remove more plaque than conventional straight-bristle toothbrushes (Avery, 1984; Shory *et al.*, 1987; Meckstroth, 1989; Chava, 2000). To the best of our knowledge, there are no studies on CBTs used in patients undergoing fixed orthodontic therapy. Therefore, the aim of this study was to determine whether CBTs alone would be more effective in plaque elimination and promoting gingival health than orthodontic toothbrushing protocols in poor-toothbrushing orthodontic patients.

Subjects and method

Thirty adolescents (12 males and 18 females) undergoing fixed orthodontic therapy participated in this study. The ages of the subjects varied between 13 and 16 years and all had Tip-Edge (TP Orthodontics, LaPorte, Indiana, USA) fixed appliances. Prior to the study, information about the study design was given to the subjects and informed consent was obtained. All subjects were right-handed and were in the second stage of orthodontic treatment (after levelling and alignment) when this study was performed. To be enrolled in the study, participants had to have dental plaque covering a minimum of 10 per cent of the total tooth

surfaces, with a careful initial plaque measurement as explained below. Exclusion criteria were as follows:

1. Presence of a systemic disease.
2. Antibiotic therapy within the previous 6 months.
3. Diagnosis of early onset periodontitis.

The same orthodontist (SA) carried out the orthodontic therapy and adjustments of the appliances in all subjects, and a different orthodontist (NA) stained the dental plaque with a plaque disclosing solution (Hager & Werken GmbH and Co.KG, Duisburg, Germany) and took photographs for quantitative evaluation (Figure 1).

A periodontist (AA), who was unaware of the study protocol, undertook the gingival index (GI) assessments and gave oral hygiene instruction along with initial periodontal therapy (oral hygiene instructions and scaling). All subjects followed each of the three toothbrushing protocols, in a randomly assigned sequence, so as to serve as their own controls. The three toothbrushing protocols were as follows (Figure 2):

1. CBT: Collis Curve (Collis-Curve Inc., Minneapolis, Minnesota, USA) is a specially designed toothbrush with curved bristles on the lateral aspect of the brush head and short straight bristles in the centre.
2. OT: This toothbrush (Oral-B Laboratories, Inc., Redwood City, California, USA) has gradually shortening straight bristles towards the centre forming a 'V' shape.
3. OT in combination with IT (OT+IT; Oral-B Laboratories, Inc.).

During the first visit, following removal of the archwires, scaling was performed and oral hygiene instruction was given. Four weeks later, baseline GI measurements were obtained and photographs of the teeth were taken. The latter was carried out after GI measurements since the dental plaque disclosing solution used for this purpose might have obscured the colour of the gingiva, leading to misinterpretation of gingival inflammation. The subjects were then assigned to one of the three toothbrushing protocols ($n=10$), each for a 4-week period, in a randomly determined sequence. The sequence of toothbrushing protocols for each numerically balanced allocation of patients was CBT–OT–OT+IT, OT–OT+IT–CBT, OT+IT–CBT–OT. There was a 4-week washout interval between each protocol. On completion of each washout period, the periodontist examined the gingiva, performed scaling where needed, and emphasized the oral hygiene measures (baseline).

The subjects were given an hourglass and standard fluoride-containing toothpaste and instructed to brush their teeth for 3 minutes according to the instructions given by the orthodontist for the assigned toothbrush, using the same toothpaste throughout the study. Patients were instructed to brush with back and forth motions with both of the toothbrushes. For the OT+IT brushing protocol, emphasis was placed on the use of IT for cleaning under wires and between
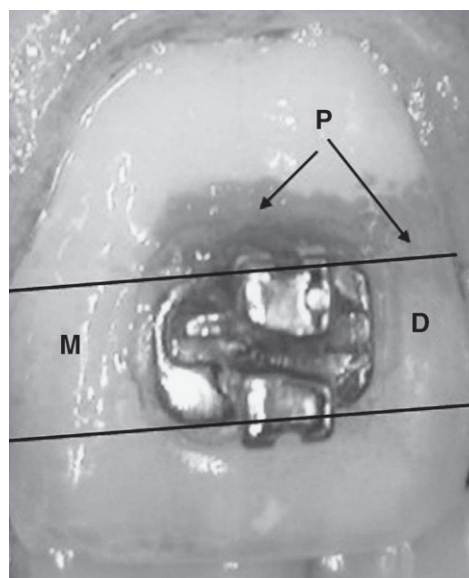

Figure 1 Dental plaque stained with plaque disclosing solution (M and D indicate the interproximal areas under archwire).
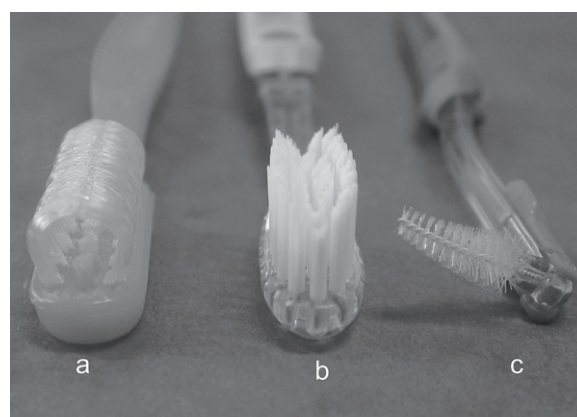

Figure 2 The toothbrushes used in the study: (a) curved bristle (b) orthodontic, and (c) orthodontic plus interproximal.

teeth following every brushing with the OT. The subjects were told not to use any other oral agents, including oral irrigators or antimicrobial mouth rinses. The subjects brushed their teeth in the clinic under supervision of one of the orthodontist just before the GI scores and photographs were taken. The maxillary and mandibular canine-to-canine teeth were used for the clinical measurements. GI measurements and photographs were obtained before (baseline) and after each toothbrushing protocol, following removal of the archwires.

The GI was recorded according to the scoring system of the World Health Organization (1978), on only the labial surfaces of the six anterior maxillary and mandibular teeth, i.e., mesiolabial, midlabial, and distolabial areas. The scores were 0=healthy gingiva; 1=mild inflammation (very little oedema and slight change in gingival colour and no bleeding on probing); 2=moderate inflammation (oedema,

hyperaemic gingiva, bleeding on probing); and 3 = severe inflammation (marked oedema and hyperaemia, sometimes ulcerations and spontaneous bleeding).

A digital photograph of each tooth (anterior teeth) of the subjects was taken with a Coolpix 4500 camera with SL-1 macro ring-light (Nikon, Tokyo, Japan). The auto-macro mode was used for all images and the camera was placed on a tripod for noise reduction. The images were 2272 × 1704 pixels in 24-bit colour depth and were stored in joint photographic experts group file format. Since the area covered with plaque and the total tooth surface area were measured on the same digital photograph and the percentage of the plaque was calculated, a fixed focal length was not used to maintain the distance between the tooth and the camera in this study. In other words, the comparison of the percentage of the areas prevented bias due to the magnification differences between the photographs of the same tooth taken at the different stages of the study.

After all three toothbrushing protocols ended and all records were collected, digital photographs were randomly numbered (NA). Firstly, the images were transferred to a computer. Plaque and tooth surface area were then digitized by one researcher (SA) who was unaware of the stages of the photographs to maintain the blind nature of the design and to prevent bias. The numbers of pixels were counted automatically and stained dental plaque was measured quantitatively on coloured macrophotographs using a special computerized image analysing system (Figure 3). This image analysis package was developed for this study in Visual Basic by a computer specialist and can be used for variable size pictures. The image analysis software automatically calculated the percentage plaque index (PPI) and the percentage of plaque retained in the interproximal regions (PIPI) under the archwire (the area between the upper and lower borders of the brackets) using the following formulae:

$$PPI = \frac{area\ of\ plaque}{area\ of\ tooth\ surface} \times 100$$

$$PPI = \frac{area\ of\ plaque\ in\ the\ interproximal\ regions}{area\ of\ plaque} \times 100$$

The plaque removal efficiency of the three toothbrushing protocols was also calculated by subtracting the baseline data from the measurements taken at the end of each protocol for PPI, PIPI, and GI scores.

Statistical analysis

The reproducibility of PPI and PIPI measurements (error study) were assessed by statistically analysing the difference between double determinations made 2 weeks apart on the digital photographs of three patients (36 teeth) selected at random. A paired-sample *t*-test at the 95 per cent confidence level showed that the difference between the first and second measurements was insignificant. Correlation analysis applied to the same measurements showed the highest *r*
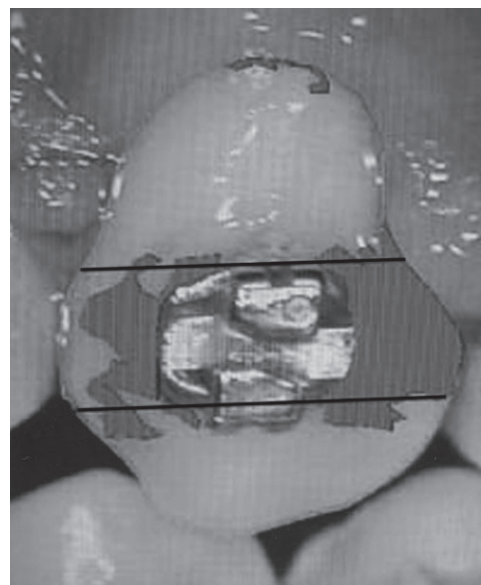

Figure 3 Measurement of percentage plaque area with digitized computerized image analysing system.

value (0.92) for maxillary central incisors and the lowest *r* value (0.83) for mandibular canines.

Repeated measures analysis of variance (multiple ANOVA) and Tukey's HSD multiple range test were used for the comparison of plaque measurements calculated for the three different toothbrushing protocols. All statistical tests were used at the 95 per cent confidence level ($P < 0.05$).

Results

The mean values of PPI, PIPI, and GIs for the three toothbrushing protocols and their baselines are given in Figure 4a–c. Multiple ANOVA showed no significant differences between the groups for baseline measurements. Thus, it was accepted that the randomly divided groups were homogeneous and the sequence of the toothbrushing protocol was used as a covariate in the statistical analysis. For all toothbrushing protocols, there was a decrease in the mean values of PPI, PIPI, and GI scores when compared with baselines. However, there was no significant decrease in the mean values of the PPI, PIPI, and GI scores for either the CBT or OT protocols ($P > 0.05$) or between these two toothbrushes in plaque removal efficiency (Table 1). However, compared with these protocols, the OT+IT protocol produced a statistically significant decrease in the mean plaque values of PPI and PIPI and in the mean GI scores ($P < 0.05$, Table 1).

Discussion

The aim of this study was to determine, using a computerized image analysing system, whether the use of a CBT alone would be more effective at dental plaque elimination than

Table 1 Comparison of the decrease in percentage plaque (total), interproximal plaque, and gingival index values with regard to three toothbrushing protocol. The figures are the percentage changes between the baseline and the final recording.

	n	Percentage plaque index			Percentage interproximal plaque			Gingival index		
		X	SD	Test*	X	SD	Test*	X	SD	Test*
CBT	30	2.0	9.7	A	4.0	10.2	A	0.21	0.28	A
OT	30	2.2	8.8	A	7.3	11.3	A	0.13	0.35	A
OT+IT	30	7.2	8.1	B	17.7	16.7	B	0.51	0.44	B

CBT, curved-bristle toothbrush; OT, orthodontic toothbrush; OT+IT, orthodontic toothbrush+interproximal toothbrush; SD, standard deviation.
*Groups showed with different letters were significantly different at the $P=0.05$ level according to Tukey's HSD test.
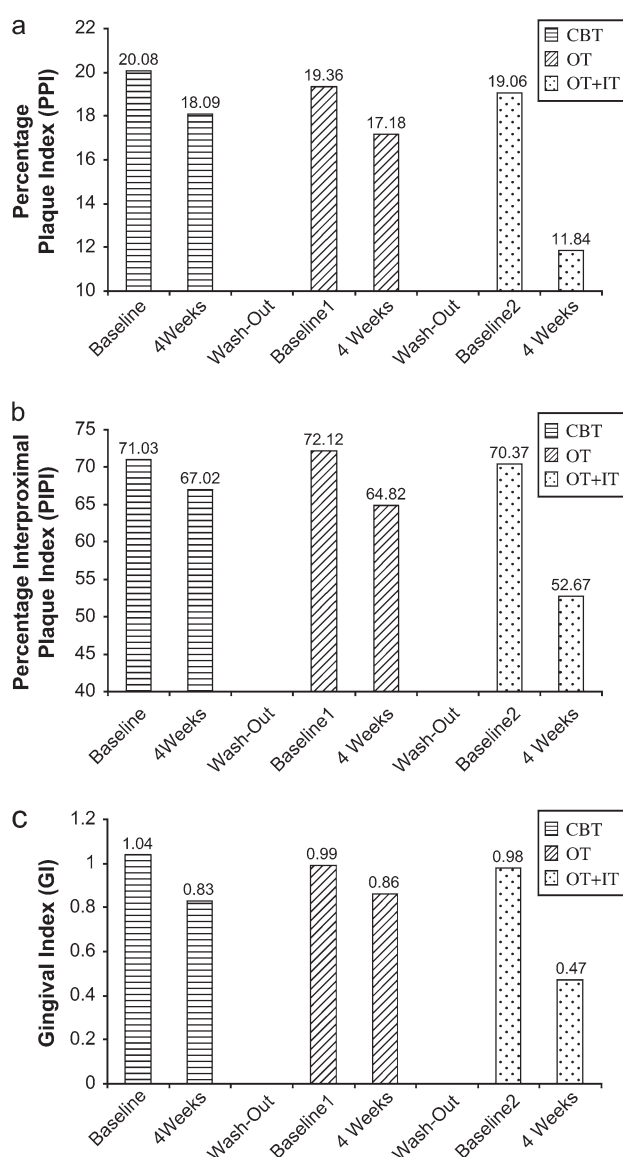
Figure 4 Mean percentage of areas with plaque at the labial (a) and interproximal (b) tooth surfaces, and mean gingival index scores (c) for the three toothbrushing protocols.

other toothbrushing protocols in poor-toothbrushing orthodontic patients. Only patients with plaque covering a minimum of 10 per cent of their total tooth surfaces participated in the study, in order to undertake a more precise comparison with regard to the efficacy of the three toothbrushing protocols in removing plaque. In this way, a standard homogenous study group was maintained, by excluding good toothbrushers from the study.

Although the sample size was relatively small, the cross-over design enabled meaningful statistical results to be achieved with only 30 patients. This design also controlled for intersubject confounders. Washout periods were included to eliminate the interaction of the three toothbrushing protocols. The patient selection criteria with regard to age, the type of fixed orthodontic appliances and archwire, and the level of oral hygiene were strictly adhered to. The patients were told to always brush for 3 minutes with the same toothpaste in order to give sufficient time for effective cleaning around the fixed attachments and to minimize variability between protocols. The brushing before each assessment was supervised by the orthodontist to ensure that every patient brushed for 3 minutes before taking measurements (GI scores and photographs). As this was carried out for all the three toothbrushing protocols, it could be tentatively suggested that results could not be influenced or biased.

For plaque measurements, mesial and distal interproximal surfaces were evaluated separately, taking into consideration the area between the upper and lower borders of the brackets since interproximal surfaces under archwires are thought to be more prone to dental plaque accumulation. The measurements were limited to the maxillary and mandibular canine-to-canine teeth because they consistently displayed a sufficient tooth surface area for study; all first molars had orthodontic bands and most of the non-extracted premolars exhibited small tooth surface areas due to bonded brackets and gingival overgrowth. It is, however, possible that these teeth did not reflect the oral hygiene level and gingival health of the whole mouth.

Soder *et al.* (1993) used a similar computerized image analysing system to measure dental plaque and found that it was highly reproducible. However, experience has shown that this system is impractical for routine and rapid

measurements of plaque, but might be useful in making quantitative and reproducible measurements in studies comparing the efficacy of different toothbrushes.

Contrary to expectations, there was no statistically significant improvement either in plaque or GI scores among patients using CBT and OT alone, compared with baseline. Although the participants were not good toothbrushers, harbouring some dental plaque at baseline, at least some improvement after initial periodontal therapy and repetitive oral hygiene motivation was expected, regardless of the type of toothbrush used, since as Drisko (2001) stated, performing a thorough periodontal debridement and frequent recall are still paramount for successful periodontal treatment. There were no overt indications of problems with patient compliance. The presence of hyperplastic gingival contours, varying from mild to moderate, especially for the lower incisors, might have prevented correct toothbrushing. Initial periodontal therapy could minimize gingival inflammation, but could not eliminate these gingival contours. Therefore, teeth with severe gingival overgrowth were excluded from the measurements.

Indeed, this study showed that orthodontic patients, particularly at this age, have great difficulty in maintaining good oral hygiene. Therefore, periodic follow-ups and repetitive reinforcement of oral hygiene instructions performed earlier than 1 month are crucial for patient motivation (Johnson *et al.*, 1985). Previous studies of CBTs have claimed that they remove more plaque than straight-bristle toothbrushes in non-orthodontic patients (Avery, 1984; Shory *et al.*, 1987; Meckstroth, 1989; Chava, 2000). However, this study reveals that the presence of orthodontic appliances complicates oral hygiene and the use of specially designed toothbrushes alone may not offer a solution for easy and effective toothbrushing.

Conclusions

Neither CBT nor the specially designed OT alone was able to remove plaque under archwires in poor-toothbrushing adolescents. Therefore, the use of interdental toothbrushes should be mandatory to remove plaque in these patients.

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