Evaluation of plaque removal of a single-headed versus a triple-headed manual toothbrush using different plaque assessment tools

Short running title: Comparison of efficiency of plaque removal

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ABSTRACT

Background: Good oral hygiene is crucial for preventing plaque build-up. It is important to note that dental plaque is a common issue that can be effectively managed with proper oral hygiene practices and regular dental care. The aim of this cross-over study was to assess dental plaque with different methods (digital and clinical plaque score) and evaluate the effectiveness of toothbrushing with a triple-headed manual toothbrush compared to a single-headed manual toothbrush in removing dental plaque.

Methods: Plaque staining was performed to assess dental plaque amounts before and after brushing with the triple-headed (test) and single-headed (control) manual toothbrush in 21 study participants after plaque was allowed to accumulate for 48 hours. Dental plaque was scored both clinically as well as digitally.

Results: Toothbrushing with a manual single-headed toothbrush and a triple-headed toothbrush were found to be equally effective when comparing plaque removal ability. Brushing time was lower when using a triple-headed toothbrush, compared to a single-headed toothbrush.

Conclusion: The triple-headed toothbrush may be a good alternative to the manual single-headed toothbrush for certain patient groups.

Keywords (Mesh): oral hygiene, dental plaque, preventive dentistry, oral health, cross-over design

CDHA Research Agenda category: risk assessment and management

INTRODUCTION

Good oral hygiene is essential to prevent diseases in the oral cavity such as caries, periodontitis and hence tooth loss (1-4). It is a prerequisite for good general health and quality of life (5-7), as poor oral hygiene is associated with serious health problems such as aspiration pneumonia (8). In addition, tooth loss as a result of oral pathology due to poor oral hygiene is associated with impaired mastication (9), which is in turn related to an increased risk for cognitive decline and malnutrition (10, 11) and subsequent further complications. Good oral hygiene is thus a key factor that cannot be neglected in the preservation of good oral and general health. Nevertheless, oral hygiene in care-dependent persons is generally poor (12, 13).

Mechanical plaque removal by means of a toothbrush has been shown to be efficient (3). This is, however, often difficult to perform by care-dependent persons due to impaired dexterity or cognition. Oral hygiene performance by care givers is also challenging. There is therefore a constant search for alternative techniques and materials to facilitate more effective mechanical plaque removal. One of these alternative methods is the triple-headed toothbrush (14-17) that is designed to brush the occlusal, oral and buccal surfaces of the tooth simultaneously. This method of toothbrushing is claimed to result in a shorter brushing time which could be very useful (18) for certain patients with limited dexterity for whom it is difficult to use a conventional one-headed toothbrush. Besides brushing time, the efficiency of plaque removal is another common study variable, traditionally assessed by plaque scoring (16). However, since clinical plaque measurements using various indexes have certain limitations, such as the subjectivity of the indices, particularly at the inter-proximal sites and intra- and inter-examiner variability (19), additional plaque measurements on digital images have been investigated recently. Earlier studies performed plaque measurements with 2D or 3D imaging techniques, revealing first evidence that these techniques are valuable (20, 21). It has been shown recently that detecting and monitoring dental plaque levels on 2D images from an intraoral camera and

on 3D images from an intraoral scanner and 3D imaging techniques is reliable. Moreover, a good agreement between the plaque values from both 2D and 3D images with the chairside clinical examination was found (22).

Although previous studies indicate better plaque removing potential of the triple-headed toothbrush as compared with the conventional single-headed toothbrush (23), it is uncertain whether subtle differences in remaining plaque (e.g. on interdental places) can be accurately detected, when only clinically assessed by plaque scoring. This study aims to measure plaque digitally using intra-oral scans and compare it to the chairside clinical plaque scoring, in order to more precisely evaluate and compare the plaque removal potential of the single- *versus* triple-headed toothbrush.

METHODS

Study population

Twenty-one healthy volunteers participated in this randomized, single-blind, controlled cross-over study. A minimum sample size of 20 was chosen, as it was consistent with similar studies where significant results were found (24, 25). Moreover, cross-over studies have the advantage to allow smaller sample sizes as the within-patient variances are lower than the inter-participant variances (26). Exclusion criteria were an active orthodontic treatment, presence of a removable prosthesis, missing teeth (with exception of the third molars) and pregnancy. Volunteers were dental students of the KU Leuven. Twenty subjects were righthanded and one subject was lefthanded. All participants had a minimum of twenty-four natural teeth present with no interposed edentulous spaces.

Study design

A cross-over study was designed, allowing both single-headed and triple-headed toothbrushes to be used by every subject in the clinical trial (Figure 1). The participants suppressed oral hygiene measures 48 hours prior to each recording to allow a sufficient amount of dental plaque to develop. Toothbrushing and the use of dental floss, interdental brushes and/or mouthwash were not allowed to be used during that period of time. The choice for a 48-hour plaque build-up rests on the fact that plaque becomes pathogenic after 48 hours (27,28). This time period was congruent with other similar scientific studies (29-31). Dental plaque was stained using a plaque disclosing solution (GUM Red-Cote™, Sunstar S.A., Etoy, Switzerland), whereafter patients were asked to thoroughly rinse their mouth 4 times with water. The amount of plaque was scored on the buccal and oral side of all upper teeth except the third molars, using the Quigley-Hein Plaque Index (QHI) (32). QHI is a plaque index that scores the amount of dental plaque on the tooth surface from 0 to 5, with 0 no plaque being present and 5 more than 2/3 of the tooth surface being covered with dental plaque. In addition, an intra-oral scan (3Shape Trios® 3, Copenhagen, Denmark) was taken to score the remaining plaque on the digital images (Figure 2). The amount of dental plaque was quantified on the 2D colour images through 2 methods: (i) visual and (ii) semi-automated, using MeshLab software (Meshlab, 2016.12) (33). All remaining plaque was analyzed, also interdental plaque if detected.

Figure 1 - Single-headed and triple-headed toothbrushes

Figure 2 – Tooth plaque on the digital images - Intra-oral scan

The subjects were provided with either a single-headed or a triple-headed manual toothbrush. No brushing instructions were given prior to the experiment, neither for the single-headed or triple-headed toothbrush in order to reproduce a real-life situation. Nevertheless, as participants were dental students, they had received instructions on the modified Bass method when using a single-headed manual tooth brush (34, 35). No specific instructions in the

curriculum, however, were given for the triple-headed tooth brush.. No toothpaste was used to evaluate the sole influence of mechanical cleaning. The duration of toothbrushing was not pre-determined and each subject continued brushing until they considered the teeth to be clean. Brushing time was recorded by the researcher who supervised the experiment. Following toothbrushing and in order to optimise visualisation, disclosure of remaining plaque was performed. Plaque measurements were performed, both clinically as well as on the images obtained via a second intraoral scan. Thereafter, the teeth were cleaned and polished using Zircate® Prophy Paste (DenstplySirona, Pennsylvania, US). The above protocol (Figure 3) was repeated for each participant after each plaque evaluation session. As this was a cross-over study, both toothbrushes were tested once by all participants. The order in which the different toothbrushes were used, was randomized. A wash-out period of at least one week during which the standard of oral hygiene care was provided, was respected.

Figure 3 – Steps taken during the study

Whereas plaque scoring was performed for all teeth (except third molars) and tooth surfaces, the semi-automated analyses on the intra-oral scan were performed on one selected tooth surface per participant and per test condition. Since most plaque accumulated on the buccal surface of the posterior teeth and since toothbrushing is generally poorer on the dominant side (36, 37) (right for right-handed persons and left for left-handed persons), the buccal surface of tooth 17 (n=20) or 27 (n=1), depending on the dominant hand of the participant, was selected for the semi-automated analysis. Using Adobe® Photoshop Elements 13 (Adobe Systems, California, US), sites with dental plaque were defined and color-coded. The modified image was subsequently imported into ImageJ/FIJI (38) and a colour histogram was generated to determine pixel counts of the tooth and of the dental plaque (Figure 4). Both counts on the

images (visual and semi-automated) were combined to determine the percentage of plaque coverage of the tooth prior to and following toothbrushing.

Figure 4 - Modified image imported into ImageJ/FIJI (38)

Statistical analysis

Mean and standard deviation were determined for the 3 recorded dental plaque indices: clinical; visual on digital image (for all teeth except third molar); and semi-automated on digital images for teeth 17/27 of the different teeth and tooth surfaces. Plaque scores and plaque reduction were calculated and statistically analysed for the differences between toothbrush types and for the clinical and digital scan. Paired t-tests were used and statistical significance was set at 5% ($p < 0.05$). The brushing time was also analysed.

Ethics approval

Approval for the study was obtained from the Institutional Ethics Committee (S61032, University Hospitals Leuven) and informed consent was given by all participating subjects (n=21). The study was registered in the Belgian Clinical Trials database (Identifier: B322201836347) and was conducted according to the ICH-GCP (International Conference on Harmonization Guidelines on Good Clinical Practice) principles.

RESULTS

A total of 21 students participated in the study. They were between nineteen and twenty-six years old and fourteen of the subjects were female (66.7%).

Results showed great correspondence between clinical and digital plaque reduction scores (Table 1), showing almost no significant differences for brushing with the single- versus

triple-headed toothbrush types. Digitally, no statistically significant differences in the plaque reduction were found for any sites in the mouth when comparing plaque reduction by means of a single-headed *versus* triple-headed toothbrush (Table 1, Figure 5). Plaque preferentially accumulated on the buccal tooth surfaces, resulting in statistically increased plaque reduction values compared to the oral surfaces (Figure 6). Furthermore, no statistically significant difference was found between single-headed *versus* triple-headed toothbrush for the plaque reduction on the buccal surfaces of both anterior and posterior teeth. For the oral surfaces, a significantly higher plaque reduction was clinically observed for the posterior oral surface after brushing with the triple-headed toothbrush (*p*-value= 0.02) (Figure 6, Table 1). Finally, using either the single- or the triple-headed toothbrush, no significant differences in plaque removal were found between dominant and non-dominant sides. Plaque scores were significantly lower after brushing for both toothbrush types (Table 2), showing that brushing with both types was effective, although the mean plaque reduction was not statistically different between both types (*p*-value= 0.22). A significant difference in brushing time between the single-headed (2'42") *versus* triple-headed (2'22") toothbrush was noted.

Figure 5 - Differences in the plaque reduction for the sites in the mouth

Figure 6 - Plaque reduction values

DISCUSSION

The present study revealed no overall significant difference in plaque removal efficiency between a conventional single-headed and a triple-headed toothbrush. This result is in line with previous studies (15-17;23) and suggests that a triple-headed toothbrush can be a valuable alternative to a conventional toothbrush. The findings were obtained through plaque scoring that was performed clinically and on digital images obtained from intra-oral scanning of all

teeth (except 3rd molars) as well as through semi-automated plaque measurements on digital images of the buccal surfaces of tooth 17 or 27.

Because plaque scoring is a rather crude measure assessing with an accuracy of 1/3rd of the tooth surface, this study aimed to evaluate whether a more accurate assessment, *i.e.* measuring the percentage of the tooth surface covered by plaque, could reveal different results. Even with a more accurate technique, however, no difference in plaque removal could be observed between both toothbrushes.

The plaque removal potential of two types of manual toothbrushes were compared in this study, although it is known that manual toothbrushing is less effective than electric toothbrushing. Electric toothbrushing still remains the golden standard for the general patient with sufficient manual dexterity and cognitive abilities (39, 40). Although an electric toothbrush can be used very efficiently by patients with limited dexterity, there is still a large part of the patient population for whom it remains difficult. For people with cognitive disabilities (e.g. people with dementia or with mental disabilities), electric brushing is sometimes difficult because the device is not accepted in the mouth (41, 42). For this reason, a manual toothbrush is often used for the latter group of patients. To increase ease of use for persons with limited dexterity or for caregivers, as well as to reduce brushing time, the manual triple-headed toothbrush seems a solid alternative to a conventional toothbrush. Brushing time is indeed observed to be shorter with a three-headed toothbrush, which favours the choice for this type of toothbrush for specific groups of patients for whom it is difficult to achieve a sufficiently long brushing time.

The study participants were mainly dental students, who are in general dental-minded and have good oral hygiene. This means that brushing with both toothbrushes was probably performed using proper technique, thereby revealing the maximum potential of both toothbrushes. However, despite using the proper brushing technique, not all accessible areas

were observed to be plaque-free. In addition, interdental plaque removal was not sufficient for either toothbrush. This finding reinforces the importance of a good interdental cleaning since no toothbrush (manual, electric, single- or triple-headed) is suitable for adequate interdental cleaning (43, 44).

Previous studies indicate that plaque removal when using the triple-headed toothbrush can vary between the participants (16). More specifically, the results suggested a correlation between the tooth morphology and sphericalness and the plaque removal efficiency. Elongated teeth, due to gingival recessions caused by periodontitis, constitute an additional factor that could hinder the effective use of the triple-headed toothbrush. Since all subjects who participated in this study had no gingival recessions nor periodontal pathology, the effect of such a condition could not be verified in the present study. Furthermore, this study was conducted in "best case" settings which cannot be compared with settings in, for example, a nursing home. There, brushing with a brush that requires more dexterity will probably be even more difficult, thereby favouring the use of the triple-headed toothbrush (45, 15). On the other hand, the above-mentioned study (16) suggests that a three-headed toothbrush may not be as efficient in this population because gingival recessions are more common in older people, hence hampering adequate cleaning cervically.

As previously known and as confirmed in the present study, plaque levels are generally higher on buccal surfaces compared to oral surfaces. The obtained results of statistically increased plaque reduction values for buccal surfaces compared to the oral surfaces are thereby logical. This result was independent of the toothbrush type used.

It has been shown that dental plaque removal is generally better on the non-dominant side, *i.e.* left side for right-handed people and right side for left-handed people, compared to the dominant side (36, 37). However, this was not observed in the present study.

This study revealed a good plaque removal ability of the triple-headed toothbrush compared to the single-headed manual toothbrush. The possibility of negative long-term effects on, for example, gingival recession formation caused by incorrect use of this toothbrush or due to inadequate plaque removal in patients with gingival recession could not be verified. A long-term study to assess these and other adverse effects is indicated.

Strengths and limitations

Although the study has a small number of participants, the techniques used for measuring plaque in this study were more accurate and innovative than the ones used in other standard plaque studies.

CONCLUSION

Conventional single-headed toothbrush and triple-headed toothbrush are found to be equally effective in removing dental plaque. The time spent for toothbrushing when using a triple-headed toothbrush was found to be significantly lower than when using a conventional toothbrush. Interdental cleaning remains an important oral hygiene factor and it is a necessary addition to toothbrushing when using any kind of toothbrush. The results of this study confirm that the use of a triple-headed toothbrush could be a good alternative compared to a single-headed manual toothbrush.

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CONFLICTS OF INTEREST

All authors declare no conflict of interest.

TABLES

Table 1. Means and standard deviations of the plaque reduction with a single-headed *versus* triple-headed toothbrush, assessed clinically and on digital images obtained from intra-oral scanning using the Quigley-Hein Plaque Index.

		Plaque reduction		Plaque reduction			
		Single-headed toothbrush		Triple-headed toothbrush		*p*-value	*p*-value
		Clinical	Digital	Clinical	Digital	Clinical	Digital
Total		1.42±0.51	1.52±0.47	1.53±0.46	1.50±0.46	0.34	0.87
Buccal		2.06±0.67	2.15±0.63	2.12±0.63	2.05±0.63	0.66	0.48
Oral		0.75±0.50	0.88±0.42	0.94±0.45	0.96±0.42	0.15	0.50
Posterior		1.43±0.50	1.53±0.45	1.61±0.47	1.60±0.47	0.19	0.60
Anterior		1.40±0.69	1.51±0.67	1.44±0.68	1.43±0.66	0.81	0.57
Posterior	Oral	0.66±0.45	0.79±0.43	0.98±0.46	0.99±0.46	0.02 **	0.12
	Buccal	2.18±0.72	2.24±0.70	2.24±0.66	2.14±0.65	0.73	0.59
Anterior	Oral	0.92±0.77	0.98±0.68	0.89±0.72	0.92±0.62	0.84	0.67
	Buccal	1.88±0.82	2.02±0.83	1.98±0.83	1.95±0.84	0.55	0.65
Posterior	Left	1.41±0.52	1.52±0.44	1.50±0.53	1.48±0.51	0.58	0.80
	Right	1.46±0.58	1.55±0.55	1.71±0.55	1.65±0.51	0.07	0.49

Anterior, incisors and canines; Posterior, premolars and molars.

** $p < 0.05$

Table 2. Means (%) and standard deviations of the plaque reduction of selected tooth surfaces quantified on digital images with a single-headed *versus* triple-headed toothbrush.

	Single-headed toothbrush	Triple-headed toothbrush	
	Mean % plaque reduction (*p*-value)	Mean % plaque reduction (*p*-value)	*p*-value
Tooth 17/27	25±13 % (0.000 ***)	31±14 % (0.000 ***)	0.22

*** $p = 0.000$

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