Original Article

Evaluating the Effectiveness of Different Manual Tooth Brush Bristle Design: A Crossover Study

Neetha Bhargava[1], Arpita Gur[2], Amit Kant[3], Akshay Bhargava[4], Shikha Saxena[5], Rohit Sharma[6]

[1]Professor and Head, [2]Former Professor, Department of Periodontology, NIMS Dental College and Hospital; [3]Private Practitioner; [4,5]Associate Professor, Department of Oral Pathology, RUHS College of Dental Sciences and Hospital; [6]Professor and Head, Department of Oral Pathology, NIMS Dental College and Hospital, Jaipur, Rajasthan, India.

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ABSTRACT

Introduction: The aim of the study was to evaluate and compare the plaque removal efficacy of four tooth brushes with different bristle designs viz. criss-cross, zig-zag, circular, and flat.

Methodology: The study was a randomized 4 sequence, cross-over design assessing the plaque removal efficacy of all four brushes on a single occasion. The study was done using 60 subjects who were divided into 4 groups (A, B, C, D). According to the sequence of toothbrush allocation, each group comprised of 15 subjects.

Results: When compared the pre and post brushing 'Plaque index' using paired t-test, all four brushes showed a significant reduction in plaque (p <0.001). Change in plaque index was not significant when compared in all four brushes but it was least in flat as compared to all others and highest in circular tooth brush type.

Conclusion: The present study shows no significant differences between the four toothbrushes, but continuous research is required to improve the toothbrush efficacy because improvement of tool than technique is a more easy approach for mass practice.

Keywords: Mechanical tooth brushing, periodontitis, tooth brush.

INTRODUCTION

Dental plaque is an organized matrix derived from salivary glycoproteins and extracellular microbial products in the form of a biofilm that forms on the hard, non-shedding surfaces in the mouth.[1] Therefore, a regular personal oral hygiene is a prerequisite for proper plaque elimination. The most common mechanical means of controlling plaque at home is tooth-brushing. There is substantial evidence that shows that plaque and gingivitis can be controlled most reliably through tooth-brushing and other mechanical cleansing procedures performed at appropriate intervals.[2]

The manual toothbrush, as we know it today, with a plastic handle and synthetic filaments was introduced in the 1920s. This made the toothbrush an affordable oral hygiene device for the mass and tooth brushing with toothpaste has become the most common oral hygiene habit.[3] Tooth brushes evolved enormously in its shape, size, and design since its launch. Most variation has been with the brush head design both in shape and filament configuration. Brushing techniques such as modified Bass-technique or modified Stillman-technique are sophisticated and complex combinations of different movements which are difficult to perform. The majority of the population is either not trained to perform a special brushing technique or suffers from a lack of skill to follow the recommendations. Toothbrushing manually, therefore, is far from perfection in controlling microbial plaque.[2] Furthermore, it is well known that most people use a simple horizontal tooth brushing action and brush their teeth for the duration markedly shorter than optimal time.[4]

Manufacturers of toothbrushes aim for innovations in the brush head design that will help to compensate for non ideal tooth brushing techniques and time. Several studies have been performed to check and compare the efficacy of different manual toothbrushes especially with reference to the arrangement of bristles but still, contradictory results have come to observation. Some authors have reached the conclusion that no toothbrush is superior to the other and user is by far the most significant variable in determining efficacy whereas studies and clinical trials performed by others, document superiority of some specific tooth-brushes.[5]

A wide variety of toothbrushes is available now a days in the market leading to creation of a dilemma in the consumer's mind with respect to efficacy of each toothbrush. The purpose of the present study was to assess the plaque removal efficacy of these different toothbrush models with different bristle designs under controlled experimental conditions and determine whether the brushes could be differentiated in terms of their effectiveness.

METHODS

The study was carried out on 60 volunteers of age group 18 to 40 years, and were selected according to the following criteria:

Inclusion criteria: (i) Healthy individuals of age group 18 to 40 years were selected because subject's method of brushing do not change. (ii) Permanent dentition with more than 20 natural teeth, having a normal periodontium.

Exclusion criteria: (i) Subjects unable to provide informed consent or comply with study protocol, (ii) Patients with cervical, buccal, and lingual restoration, (iii) Patients with open bite and incompetent lips, (iv) Pregnant or lactating women, and (v) Patients who have pathological periodontal pocket.

Four types of tooth brushes with different bristle arrangement were used in this study.

a. Criss cross- It is a multilevel, standard head brush with rounded toe. Soft multitufted nylon bristles are arranged in four rows. The bristle length arranged in three levels. Bristles attached with head in such angular fashion that the tufts of lateral rows shows opposite angulations from central rows and this arrangement gives appearance of cross formation by bristles.

Figure 1: Tooth brushes with different bristle design side views.

b. Zig-zag- It is a multilevel, standard head brush with rounded toe. Soft multitufted nylon bristles arranged in four vertical rows. The bristle is cut in tapered length and arranged in multiple horizontal lines in which the longest bristle is in center of the line and tapered towards anterior and posterior, this arrangement also form multiple horizontally arranged grooves. Such arrangement gives appearance of zig-zag formation by bristles when viewed by side.

c. Circular- This type is a multilevel, standard head brush with soft multitufted nylon bristles arranged in two circles and each circle made up of two rows. The bristles length is arranged in two levels in which the inner row of each circle has shorter bristles than outer row.

d. Flat- It is a conventional flat, four-row, multitufted, soft, nylon brush, with a standard head. All the bristles at same level have similar length.

The two tone dye Alphaplac manufactured by DPI was applied on the vestibular surfaces of the teeth on both sides, after which the subjects were instructed to not rinse for 30 seconds, so the dye spread uniformly over the teeth. Thirty seconds later, they rinsed vigorously three times for 10 seconds with water. The amount of disclosed plaque was scored clinically by means of the Turesky and Gilmore modification of Quigley-Hein plaque index after 24 hours of unrestrained plaque growth and following after brushing.

The study was done using 60 participants divided into 4 groups (A, B, C, D). According to the sequence of toothbrush, each group consisted of 15 subjects distributed randomly. The subjects were allocated toothbrushes based on their group. On the first day of each phase, the subjects were rendered plaque free by performing scaling and then asked to refrain from the oral hygiene practice for next 24 hours. On day 2, the subjects were assessed for plaque prior to brushing according to the criteria of Turesky and Gilmore modification of Quigley-Hein plaque index. Plaque was assessed on the buccal and lingual surface of all teeth except 3rd molar using plaque disclosing solution. The subjects were allocated the toothbrushes and asked to brush for 3 minutes with the same technique which the patient was following daily, again the plaque score was calculated after brushing using the same index. Then wash out period of 4 days was allowed before the next phase begins, during

which the subjects returned to their normal oral hygiene practices, during this phase the plaque score was not monitored. Next phases were conducted in the similar manner but the type of toothbrush bristles were changed, where the subject receives the toothbrush of different bristles design. Mean pre-brushing and post-brushing plaque index for each subject was determined by adding all the respective individual plaque scores and dividing the sum by the total number of surfaces examined. The results obtained were statistically analyzed.

Variables were presented as mean and standard deviation. Statistical tests were applied as Student's Paired t-test was used to see the change in variables with respect to time and one way ANOVA followed by post-hoc test was used for multiple group comparison. p-value less than 0.05 considered as significant at 95% confidence level. The statistical software SPSS version 18.0 was used in the analysis.

RESULTS

A total of 60 participants in the age range of 18-40 years (mean age of 28.7 years) who were eligible and willing to participate were included in the study. Pre and post brushing plaque index were taken on every visit. Results obtained from the study were then statistically analysed.

The mean plaque index before brushing for brush criss-cross, zig zag, circular, and flat were 2.775 (±0.420), 2.821 (±0.399), 2.839 (±0.413), and 2.787 (±0.407), respectively. The mean plaque index after brushing were 0.598 (±0.119), 0.618 (±0.420), 0.604, and 0.727, respectively. When compared the pre and post brushing using paired t-test all four brushes show significant reduction in plaque, the p value was <0.001 (Table 1, Figure 2).

The plaque reduction by different brushes was compared by using one way ANOVA test. Plaque index score reduction was 2.178 (±0.403), 2.204 (±0.370), 2.235 (±0.404), and 2.060 (±0.409) for criss cross, zig zag, circular, and flat tooth brush, respectively. Also, the mean plaque score reduction with all type of tooth brush is 2.169 (±0.400). There was no significant difference in plaque reduction by different brushes. The plaque reduction after using different types of brushes was non-significant as p-value was greater than 0.05 (Table 2).

Table 1: Comparison of pre to post brushing plaque index score by using paired t-test

		N	Mean	Std. deviation	Mean difference	t-value	p-value
Pair 1	PI Criss-Cross Pre	60	2.775	0.420	2.17767	41.886	<0.001
	PI Criss-Cross Post	60	0.598	0.119			
Pair 2	PI Zig-Zag Pre	60	2.821	0.399	2.2035	46.155	<0.001
	PI Zig-Zag Post	60	0.618	0.132			
Pair 3	PI Circular Pre	60	2.839	0.413	2.23483	42.885	<0.001
	PI Circular Post	60	0.604	0.134			
Pair 4	PI Flat Pre	60	2.787	0.407	2.05967	39.047	<0.001
	PI Flat Post	60	0.727	0.124			

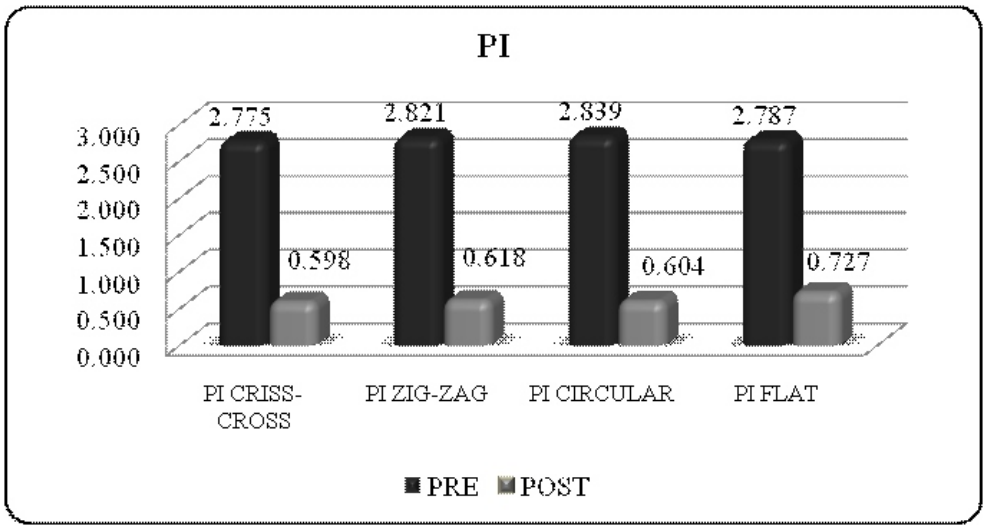

Figure 2: Bar graph demonstrating pre and post brushing plaque index of different brushes.

The percentage of plaque reduction after brushing for bristle criss cross, zig zag, circular, and flat was 78.07, 77.91, 78.38, and 73.39 respectively (Table 3). The reduction in plaque index by all the brush designs was statistically significant.

When plaque reduction by one brush is compared to other three brushes using 'post hoc' test no significant difference was seen with any brush (p value is >0.001) (Table 4).

When percentage reduction in plaque index was compared between different brushes flat toothbrush showed significantly less percentage plaque reduction compared with other three, as table 5 shows p value less than 0.001 in pair 3, 5 and 6.

DISCUSSION

Plaque removal is essential to prevent dental and periodontal diseases. Toothbrushes do this job by disrupting the plaque mechanically. Some parameters like bristle softness and brushing interval are well defined and accepted.[6] Bristle arrangement and designs are however changing day by day and each claims better effectiveness for plaque removal. Although several workshops and reviews have consistently concluded that there is no superior design of manual toothbrush, yet different companies are coming out with different designs, each claiming superiority, backed by the results of their own clinical research team.

Different studies have been conducted for different time periods and no fixed duration has been agreed upon. Studies ranging from single use to 1 month to 6 months have been conducted. In this study, a cross-over design assessing the efficacy of four different bristle designs of toothbrushes in single-use plaque removal was employed. Single-use plaque removal studies are considered to be as accurate as multiple visit plaque removal studies in assessing the efficacy of brushes.[7-9]

In this study, four toothbrushes with different bristle designs were selected. Pre-brushing and post-brushing plaque scores were noted for whole dentition except for 3rd molars. Other dental conditions e.g. crowding, presence of removable or fixed prosthesis, open bite, and incompetent lips were also excluded. Cervical, buccal, or lingual restoration bearing teeth were also excluded because these lead to greater possibilities for plaque accumulation. For the quantitative assessment of plaque, Gilmore-Glickman Modification of Hein Plaque Index was chosen. The choice of the index was based on the fact that with this index all natural teeth (except third molars) can be assessed for plaque and it provides a more sensitive and accurate evaluation of brushing effectiveness compared to other indices used in other studies,[10,11] where only certain designated teeth were assessed. To give emphasis on the selected variable i.e. toothbrush bristle design, all other parameters were kept constant e.g. toothbrush bristle texture (softness). In addition, all volunteers used their own methods for brushing, as for the four toothbrushes used, the technique as per same volunteer remained the same.

While comparing the pre-brushing and post-brushing mean plaque scores from tables, it can be noted that, for flat-bristle designed toothbrush, the mean plaque score reduction was 2.060, for criss-cross bristle designed toothbrush the reduction was 2.178, zig-zag bristle designed toothbrush showed a reduction of 2.204,whereas

Table 2: Comparison of reduction in plaque index (PI) by different brushes using one way ANOVA test

	N	Mean of difference	Std. deviation	Minimum	Maximum	f-value	p-value
Criss-Cross	60	2.178	0.403	0.89	2.84		
Zig-Zag	60	2.204	0.370	1.07	2.79		
Circular	60	2.235	0.404	1.11	3.13	2.233	0.085
Flat	60	2.060	0.409	1.05	2.68		
Total	240	2.169	0.400	0.89	3.13		

Table 3: Descriptive statistics of percentage change in plaque index

	Descriptive statistics				
	N	Minimum	Maximum	Mean	Std. deviation
PI Criss-Cross % change	60	60.11	91.33	78.07	4.97
PI Zig-Zag % change	60	64.14	91.33	77.91	4.63
PI Circular % change	60	59.92	87.26	78.38	5.42
PI Flat % change	60	53.81	85.47	73.39	5.78

Table 4: Comparison of plaque index reduction by different brushes using post hoc test

(I) Type	(J) Type	Mean difference (I-J)	p-value
Criss-Cross	Zig-Zag	–0.026	0.984
	Circular	–0.057	0.859
	Flat	0.118	0.364
Zig-zag	Criss-Cross	0.026	0.984
	Circular	–0.031	0.973
	Flat	0.144	0.196
Circular	Criss-Cross	0.057	0.859
	Zig-Zag	0.031	0.973
	Flat	0.175	0.076
Flat	Criss-Cross	–0.118	0.364
	Zig-Zag	–0.144	0.196
	Circular	–0.175	0.076

Table 5: Comparison of percentage change between different types of tooth brushes

		N	Mean	Std. deviation	Mean difference	t-value	p-value
Pair 1	PI Criss-Cross % change	60	78.07	4.975	0.16	0.33	0.744
	PI Zig-Zag % change	60	77.91	4.629			
Pair 2	PI Criss-Cross % change	60	78.07	4.975	-0.31	0.44	0.659
	PI Circular % change	60	78.38	5.423			
Pair 3	PI Criss-Cross % change	60	78.07	4.975	4.69	7.92	<0.001
	PI Flat % change	60	73.39	5.777			
Pair 4	PI Zig-Zag % change	60	77.91	4.629	-0.47	0.65	0.519
	PI Circular % change	60	78.38	5.423			
Pair 5	PI Zig-Zag % change	60	77.91	4.629	4.52	6.90	<0.001
	PI Flat % change	60	73.39	5.777			
Pair 6	PI Circular % change	60	78.38	5.423	4.99	7.52	<0.001
	PI Flat % change	60	73.39	5.777			

circular bristle designed toothbrush showed a reduction of 2.235. This suggests that all four toothbrushes have shown plaque reduction. The reduction was also found to be statistically significant as the p-values were less than 0.05. This is in favour of most of the studies performed previously.[12,13] However, it seems evident that the difference between pre and post-brushing plaque scores for flat bristle designed toothbrush was less as compared to the rest of three brushes.

Comparing percentage reduction for the four toothbrushes reveals that circular bristle designed toothbrush showed maximum plaque reduction. Minimum plaque reduction was observed for flat bristle designed toothbrush. Less percentage reduction for flat type and a greater percentage reduction for other three type toothbrushes could be due to a variety of reasons. For example, most of the population is habitual for using horizontal scrub tooth brushing method and simple brush design was not so effective till they were used in proper brushing technique. Complexly designed toothbrushes have special bristle arrangement so they are effective when used even without a particular technique.

Another reason that can be correlated is the single level bristles of the flat type of brush. For the rest of three toothbrushes, though as seen from the side, surface of the toothbrush head showed varied level bristle tufts. Such bristles provided more adapted stroke when they were put perpendicularly to the uneven tooth surface and hence delivered more plaque removal. But for flat type, optimum reach was not possible due to contoured nature of tooth surface. Moreover, a toothbrush with bristles, arranged at multiple levels are easy to be adapted to the tooth surface with one's own technique of brushing rather than single level.

The plaque scores were similar during all the four test periods. The results of the study showed no statistically significant differences between the four brushes. This is in line with the study by Bergenholtz et al[14] who conducted a similar study comparing the toothbrush having v-shaped bristles with a flat-trim toothbrush and concluded no significant differences between the toothbrushes. It is also similar to the studies by Staudt[15] who conducted a study to compare the efficacy of three toothbrushes with convex

bristles, multilevel bristles, and flat-trim bristles. This study used a computer-based planimetric plaque index, which is considered to be superior in terms of sensitivity, objectivity, and reliability. The results of their study were similar to that of the present study in that no toothbrush could prove significant superiority over the other brushes. Results of this study also support the study done by Sripriya et al[12], they did similar study on subjects of lesser age group in which sixteen subjects aged 14-15 years were selected. However, this study is in contradiction to the study by Kieser et al[16], where all brushes reduced plaque to a similar degree. The positive results in that study can be attributed to the use of Silness and Loe plaque index, which scores plaque on six teeth and does not take the plaque scores on the remaining teeth into consideration.

The present single-use comparative study of plaque removal effectiveness scored plaque on all tooth surfaces using a well accepted index and showed highly significant plaque reductions from baseline with all four models of manual toothbrushes. But separate consideration for plaque reduction was not taken for surfaces known to be difficult-to-reach during normal brushing i.e. along the gum line and between the teeth. Also the effect of different bristles on brushing time is not accounted if any bristles type is more effective with lesser brushing time.

CONCLUSION

Varieties of tooth brushes are available and continuously coming in market and only a few commonly used and widely available designs are used for the study. May be other designs give some beneficial effect. So a vast study including more bristle design should be taken into consideration.

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Corresponding Author

Dr Neetha Bhargava, A-48, Aacharya Vinobha Bhave-nagar, Vaishali Nagar, Jaipur, Rajasthan, India- 302021.

email: veekshya@gmail.com