Comparison of Irrigation to Floss as an Adjunct to Tooth Brushing: Effect on Bleeding, Gingivitis, and Supragingival Plaque

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Abstract

- Objective: The purpose of this twenty-eight day, randomized, single-blind clinical trial was to assess the efficacy of the addition of daily oral irrigation to both power and manual tooth brushing, compared to a traditional regimen of manual tooth brushing and flossing, to determine which regimen had the greatest effect on the reduction of gingival bleeding, gingivitis, and supragingival plaque.
- Methodology: The study was designed for a total of 105 subjects to participate in a twenty-eight day trial, with 35 subjects randomly assigned to one of three groups: Group I-manual toothbrush and floss; Group 2-manual toothbrush and dental water jet; and Group 3-sonic toothbrush and dental water jet. All subjects received written and verbal instructions for using their regimens. Subjects were asked to brush for a timed two minutes, twice per day, with the brush and the dentifrice provided, and to refrain from using any additional oral hygiene aids. Subjects using the dental water jet were instructed to use the water jet on a medium setting, irrigating once per day with 500 ml of luke warm water. Subjects using the dental floss were instructed to use the floss once daily. Subjects were examined by two calibrated examiners, and data were collected at baseline (BSL), 14 days (DI4), and 28 days (D28). Subjects were asked to abstain from any oral hygiene for 12 hours prior to each study visit. Subjects were scored using the Carter and Barnes Bleeding Index, Loe and Silness Gingival Index, and the Proximal/Marginal Plaque Index. Mean scores on the three indices for the three groups were used for statistical analysis at each time point. Additionally, the means were used for comparisons as change from baseline and percent change from baseline at D 14 and D28. The significance of percentage change in each index from baseline to DI4 and D28 was evaluated using a one-tailed t-test. Significant differences are reported at a::; 0.05 for these planned group comparisons.
- Results: Thirty-one subjects in Group 1,32 subjects in Group 2, and 32 subjects in Group 3 completed the study. Bleeding Index: Groups 2 and 3, the irrigation groups, were statistically significantly more effective than Group I in reducing the bleeding index at D 14 and D28, whether measured by mean reduction or percentage reduction. Gingival Index: At D 14, both irrigation groups demonstrated a statistically significantly greater reduction in the gingival index compared to brushing and flossing for the facial surfaces. There was no significant difference between groups for the lingual surface at D14. At D28 there was a significant difference between Groups I and 2 for both the facial and lingual surfaces. Plaque Index: There was one significant difference between groups for the plaque index measured on the lingual surfaces. The manual toothbrush and floss were less effective than the sonic toothbrush and irrigation. Group 3 was also significantly better than Group I in reducing the plaque index on the facial surfaces at both DI4 and D28. On plaque percentage reduction on the facial surface, Group 2 was significantly better than Group I at D14. There was no statistical difference between Group I and Group 2 at D28.
- **Conclusion: The results of this clinical trial indicate that when combined with manual or sonic tooth brushing, oral irrigation is an effective alternative to manual tooth brushing and dental floss for reducing bleeding, gingival inflammation, and plaque removal.**

(J Clin Dent 16:71-77, 2005)

Introduction

Research over the last decade has established that the etiology of periodontal disease is a bacterial infection mediated by the host inflammatory response. [1-4] While effective daily removal or disruption of dental plaque is essential, it may not be enough to completely prevent the disease. One oral hygiene device, the oral irrigator, has demonstrated its effectiveness in decreasing the by-products of the host inflammatory response associated with gingivitis and periodontitis when used on a daily basis.[5,6]

The daily use of oral irrigation has been shown to reduce dental plaque, calculus, gingivitis, bleeding, probing depth, periodontal pathogens, and host inflammatory mediators.[5-20] Of these clinical parameters, all have demonstrated the same consistency in outcomes over the years, with the exception of supragingival plaque reduction. This single incongruence has led some dental professionals to reject irrigation despite evidence that it improves periodontal health.

One reason for this inconsistency may be that traditional dental plaque indices provide a quantitative measure of plaque. Emerging information indicates plaque is a biofilm. Research demonstrates that dental biofilm is a more complex configuration than previously believed, leading many to speculate that traditional indices are inadequate because they fail to evaluate qualitative changes. This may be the case with home irrigation as several researchers have found that irrigation is capable of reducing subgingival pathogens, thus altering biofilm composition.[7],9,11,12,14,ls,2o,21 In addition to reducing subgingival pathogens, oral irrigation irreparably damages bacterial cells. Plaque that remains on irrigated teeth contains bacteria that have ruptured cell walls or incomplete cellular contents, rendering the plaque less potent and less pathogenic.[22] Concomitant to damaging bacterial cells, oral irrigation is effective in removing endotoxins that are produced in the immune response to periodontal infections.[23]

The strongest and most consistent evidence for the benefit of home irrigation is its ability to reduce gingivitis and bleeding.5-8,10,12-21 Newman, *et al.*[8] had subjects add daily irrigation with water to routine oral hygiene (brushing and flossing), and found enhanced gingivitis and bleeding reductions over brushing and flossing alone. Others have found similar findings,S,6,8 including Flemmig[lO] who observed a 50% greater reduction in bleeding over routine oral hygiene. Drisko's recent research indicated that when daily irrigation with water was added to a regular oral hygiene home regimen, a significant reduction in probing depth, bleeding on probing, and gingival index was observed. ıı Further, a host modulatory response, as evidenced by changes in the cytokine levels of IL-lB and PGE_2 which are associated with destructive changes in inflamed tissues and bone resorption, also occurs with the use of oral irrigators.[s]

Traditionally, tooth brushing-power or manual-and flossing have been considered the standard for routine plaque removal and gingivitis reduction. One problem with this regimen is that compliance with floss is low.[24] Therefore, the purpose of this study was to assess the efficacy of adding daily oral irrigation to both power and manual tooth brushing, compared to a traditional regimen of manual tooth brushing and flossing, to determine which regimen had the greatest effect on the reduction of bleeding, gingivitis, and supragingival plaque.

Materials and Methods

Subjects

Adult subjects between 19 to 70 years of age were recruited for this study without regard to sex or ethnic origin. All subjects we\e required to have a medical history indicative of general good health, and to sign an informed consent form approved by the University of Nebraska Medical Center Institutional Review Board. Along with good general health, inclusion criteria included a minimum of 20 evaluable teeth, not including third molars, a minimum mean plaque score of 2.0, and 50% bleeding sites. Onry subjects that reported at least one-time daily brushing were accepted. The exclusion criteria were:

- Systemic disease, such as AIDS, leukemia, cirrhosis, sarcoidosis, diabetes mellitus, or hepatitis;
- A history of rheumatic fever or the need for antibiotic premedication for heart valve replacement, heart valve dysfunction, heart valve prosthesis, or other artificial joints;
- Prophylactic or therapeutic antibiotic use within two months prior to the start of the study;
- Pregnancy or hormone therapy;
- Visual signs of rampant caries or advanced periodontitis;
- Fixed orthodontic appliances or removable prosthodontic appliances; and
- Lack of dexterity required for tooth brushing, flossing, or irrigating.

Study Design

This single blind, four-week study included 105 subjects, with 35 subjects randomly assigned to each of three groups: Group 1: a manual toothbrush (Oral-B® 35, Oral-B Laboratories, Boston, MA, USA) and dental floss (Reach FlOSSTM, Johnson and Johnson, Skillman, NJ, USA); Group 2: a manual toothbrush (Oral-B® 35) and a Waterpik® dental water jet (WP-60W, Waterpik Technologies, Fort Collins, CO, USA); Group 3: Waterpik sonic toothbrush (SR-700W), and a Waterpik dental water jet (WP-60W).

The manual brush used by subjects in Groups 1 and 2 was a standard soft-bristle brush, with 35 rows of tufts and flat bristles; the floss used was unwaxed and mint-flavored. The Waterpik sonic toothbrush (Figure 1) used by Group 3 utilizes 30,000 strokes per minute with a back-and-forth motion. 'Additionally, it has an electronic feedback mechanism that automatically senses brushing pressure and adjusts the brush speed for optimal performance. The Waterpik dental water jet (Figure 1) utilizes a pulsating stream of water. It has a combination of 1,200 pulsations and a pressure range from 20-90 psi.

Subjects were examined by two experienced examiners who were calibrated by consensus. Each examiner examined the same subjects throughout the study. Data were collected at baseline

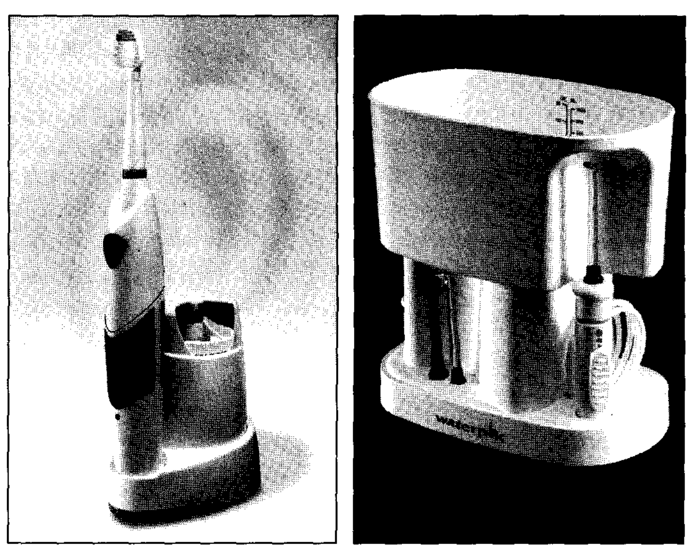

Figure 1: *WaterpiJ(" Sonic Toothbrush SR 700 and WaterpiJ(" Dental Jet WP-60W*

(BSL), 14 days (D14) and 28 days (D28). Subjects were asked to abstain from any oral hygiene for 12 hours prior to each study visit.

After baseline data were recorded at the first visit, subjects received the implements required for their assigned oral hygiene regimen. Irrigating instructions (manufacturer's recommended instructions for the Waterpik dental water jet), the Modified Bass technique for the manual toothbrush, and standard of care instructions for flossing were given verbally and in writing. The floss, toothbrushes, and water jet were also demonstrated to each subject on a manikin. Subjects were asked to brush for two minutes (timed), twice per day with the provided brush, and to refrain from using any additional oral hygiene aid not assigned, including therapeutic mouth rinses. The flossing group was instructed to floss once daily in the evening. Correct technique (wrapping the floss around middle fingers, using the index fingers and thumb to guide the floss, contour around the side and move up and down the tooth) was communicated in writing and verbally. The irrigation groups (Groups 2 and 3) were instructed to put the pressure control knob on medium (4 setting or 70 psi), and to maintain this setting throughout use. Irrigation was done once daily in the evening with 500 ml of luke warm water.

Gingival bleeding was scored at interproximal sites of all teeth utilizing the Carter and Barnes Bleeding Index,25 a binary index denoting 0 for no bleeding and 1 for bleeding. Gingivitis was scored at six sites per tooth (mesial, central, and distal locations on the facial and lingual sides) utilizing the Loe and Silness Gingival Index.[26] Prior to scoring the plaque index, subjects had their plaque disclosed with a disclosing solution (FDC #3 red). Supragingival plaque was scored utilizing the Proximal/Marginal Plaque Index.[27] This dental plaque scoring method has six levels designated 0, 1,2,3,4, and 5. The indices were designated special values for sites that were missing or not scored (Figure 2).

Carter and Barnes Bleeding Index 0 =
No Bleeding
1 = Bleeding

Number of Sites Bleeding = % of Bleeding
Total Number of Sites

Loe and Silness Gingival Index 0 =
Normal gingiva
1 = Mild inflammation-slight changes in color, slight edema; no bleeding upon probing
2 = Moderate inflammation-redness, edema and glazing; bleeding upon probing
3 = Severe inflammation-marked redness and edema, ulceration, tendency for spontaneous bleeding

ProximallMarginal Plaque Index
0= No Plaque
1 = Separate flecks of plaque covering less than 1/3 of the area.
2 = Discrete areas or bands of plaque covering less than 1/3 of the area
3 = Plaque covering 1/3 of the area
4 = Plaque covering more than 1/3 but less than 2/3 of the area 5 =
Plaque covering 2/3 or more of the area

Figure 2. *Indices for measurement of bleeding, gingival inflammation, and plaque.*

Statistical Analysis

The three variables of interest for this clinical trial were the bleeding index, gingival index, and plaque index. Each index was measured at numerous specific anatomical sites for each subject at each of the three time points: BSL, D14, and D28. Mean index values within subjects were calculated for facial and lingual sites separately for each index at each time point. The percentage change in each mean index from baseline was calculated for each subject for each follow-up measurement. The percentage change in each index was calculated for each subject by dividing the difference in subject means (follow-up - baseline) by the baseline mean value (times 100 to express as percent).

The significance of percentage change in each index from baseline to each follow-up was evaluated using a one-tailed t-test. Group 1 was used as a control reference for comparison to Group 2 and Group 3. Statistical comparisons between groups were done using one-tailed t-tests. Actual p-values are reported with significant differences accepted at a :s 0.05 for these planned group compansons.

Data management was accomplished using FileMaker Pro 4 (Claris, Santa Clara, CA, USA). Statistical analysis was done using IMP 5.1.2 (SAS Institute, Cary, NC, USA).

Results

At the conclusion of the study there were 31 subjects in Group 1, 32 subjects in Group 2, and 32 subjects in Group 3. Illness, requiring treatment with antibiotics, caused nine subjects to be dismissed; one subject was dismissed due to illness requiring treatment with corticosteroids. The dismissals appeared to be random across the groups and likely did not affect the outcome. There were no adverse events during the study.

Overall Findings

The means and standard deviations on the bleeding index, gingival index, and plaque index are provided in Table I. The mean values for the bleeding index, gingival index, and plaque index were reduced from baseline at both Dl4 and D28 followup times, on facial and lingual sites, for each of the three groups. The gingival health measures of the bleeding index and gingival index showed a statistically significant percentage reduction in each group at each follow-up time as indicated by asterisks. Percentage reduction in plaque index was statistically significant for all groups and all follow-up times, except for Group 1 at Dl4 of follow-up. In that case, the mean.percentage reduction in plaque index was not significantly greater than zero.

Bleeding Index for Facial Surfaces

The percent reduction in the bleeding index on the facial surface (Table II) was greater in Group 2 (64.2) than Group 1 (47.3) at Dl4 (p = 0.0180). At D28, the Group 2 percent reduction (59.2) was also significantly greater than that for Group 1 (30.6) at p = 0.0014. For Group 3, the facial percent reduction in bleeding index was 60.6 at D14, which was significantly greater than 47.3 for Group 1 (p = 0.0493). At D28 for Group 3, the facial percent reduction in bleeding index was 50.6 versus 30.6 for Group 1, a significant statistical difference at p = 0.0172.

Table I
Overall Means and Standard Deviations of Raw Scores
for Gingival Health Measures and Plaque Index

	Bleeding Index		Gingival Index		Plaque Index	
Group I	Mean	SD	Mean	SD	Mean	SD
Baseline (facial)	0.44	0.23	1.28	0.20	3.37	0.63
2-weeks (facial)	0.25	0.21*	1.13	0.17*	3.14	0.51*
4-weeks (facial)	0.27	0.20*	1.14	0.15*	2.99	0.41*
Baseline (lingual)	0.60	0.21	1.37	0.19	3.49	0.34
2-weeks (lingual)	0.39	0.19*	1.23	0.18*	3.27	0.32*
4-weeks (lingual)	0.40	0.21*	1.23	0.17*	3.18	0.34*
Group 2						
Baseline (facial)	0.47	0.22	1.29	0.18	3.36	0.54
2-weeks (facial)	0.18	0.16*	1.06	0.12*	2.95	0.64*
4-weeks (facial)	0.17	0.13*	1.08	0.10*	3.04	0.51*
Baseline (lingual)	0.63	0.23	1.41	0.23	3.60	0.47
2-weeks (lingual)	0.39	0.24*	1.21	0.22*	3.26	0.60*
4-weeks (lingual)	0.34	0.19*	1.20	0.17*	3.22	0.44*
Group 3						
Baseline (facial)	0.49	0.24	1.29	0.21	3.43	0.59
2-weeks (facial)	0.20	0.22*	1.07	0.16*	2.81	0.64*
4-weeks (facial)	0.23	0.16*	1.12	0.12*	2.83	0.67*
Baseline (lingual)	0.60	0.19	1.38	0.19	3.64	0.41
2-weeks (lingual)	0.36	0.24*	1.21	0.18*	3.25	0.42*
4-weeks (lingual)	0.37	0.23*	1.22	0.17*	3.27	0.43*

*Percent reduction values significantly different from zero by I-tailed t-test at 0.05 (all significant except facial PI in Group I at 2 weeks).

Table II
Bleeding Index

	Percent Reduction	
Group I	Mean	SD
Baseline (facial)		
2-weeks (facial)	47.3	27.8*
4-weeks (facial)	30.6	48.2*
Baseline (lingual)		
2-weeks (lingual)	31.2	32.2*
4-weeks (lingual)	26.9	48.2*
Group 2		
Baseline (facial)		
2-weeks (facial)	64.2	29.6*
4-weeks (facial)	59.2	25.4*
Baseline (lingual)		
2-weeks (lingual)	40.7	35.3*
4-weeks (lingual)	37.7	46.3*
Group 3		
Baseline (facial)		
2-weeks (facial)	60.6	36.4*
4-weeks (facial)	50.6	34.1*
Baseline (lingual)		
2-weeks (lingual)	41.0	36.1*
4-weeks (lingual)	36.2	39.1*

*Percent reduction values significantly different from zero by I-tailed t-test at 0.05 (all significant except facial PI in Group 1 at 2 weeks)

Table III
Gingival Index

	Percent Reduction	
Group 1	Mea	SD
Baseline (facial)		
2-weeks (facial)	11.3	7.1*
4-weeks (facial)	9.9	10.0*
Baseline (lingual)		
2-weeks (lingual)	12.4	11.0*
4-weeks (lingual)	9.4	10.7
Group 2		
Baseline (facial)		
2-weeks (facial)	17.1	7.9*
4-weeks (facial)	15.1	10.3*
Baseline (lingual)		
2-weeks (lingual)	13.5	11.6*
4-weeks (lingual)	14.2	10.9*
Group 3		
Baseline (facial)		
2-weeks (facial)	15.8	11.8*
4-weeks (facial)	11.4	13.5*
Baseline (lingual)		
2-weeks (lingual)	11.9	10.2*
4-weeks (lingual)	10.8	11.9*

*Percent reduction values significantly different from zero by I-tailed t-test al 0.05 (all significant except facial PI in Group 1 at 2 weeks)

Bleeding Index for Lingual Surfaces

The percent reduction in bleeding on the lingual surfaces (Table II) was not significantly different between Group 1 and either Group 2 or Group 3 at either Dl4 or D28. For Groups 1, 2, and 3, the mean percent reductions in bleeding index at Dl4 on the lingual surfaces were 31.2, 40.7, and 41.0, respectively. For Groups 1, 2, and 3, the mean percent reductions in bleeding index at D28 on the lingual surfaces were 26.9,37.7, and 36.2, respectively.

Gingival Index for Facial Surfaces

The percent reductions in the gingival index at D14, for Groups 1, 2, and 3 on facial surfaces (Table III) were 11.3, 17.1, and 15.8, respectively. Group 1 was significantly less compared to both Group 2 (p = 0.0076) and to Group 3 (p = 0.0279). The percent reductions in the gingival index at D28 for Groups 1, 2, and 3 on facial surfaces were 9.9,15.1, and 11.4, respectively. Group 1 was significantly less compared to Group 2 (p = 0.0350), but not Group 3 (p = 0.3022).

Gingival Index for Lingual Surfaces

The mean percent reductions in the gingival index at D 14, for Groups 1,2, and 3 on lingual surfaces (Table III) were 12.4, 13.5, and 11.9, respectively. Group 1 was not significantly different from either Group 2 (p = 0.3381) or Group 3 (p ~ 0.4278) on this measure. The percent reductions in the gingival index at D28, for Groups 1,2, and 3 on lingual surfaces were 9.4, 14.2, and 10.8, respectively. Group 1 was significantly less compared to Group 2 (p = 0.045), but not significantly different from Group 3.

Plaque Index for Facial Surfaces

The mean percentage reductions in the plaque index at D14, for Groups 1, 2, and 3 on facial surfaces (Table IV) were 5.1, 11.5, and 17.6, respectively. Group 1 was significantly less tharJ

Table IV
Plaque Index

	Percent Reduction Mean	Percent Reduction SD
Group I		
Baseline (facial)		
2-weeks (facial)	5.1	14.3 *
4-weeks (facial)	9.0	17.3 *
Baseline (lingual)		
2-weeks (lingual)	5.7	10.4 *
4-weeks (lingual)	8.1	11.9
Group 2		
Baseline (facial)		
2-weeks (facial)	11.	15.5*
4-weeks (facial)	8.8	12.4*
Baseline (lingual)		
2-weeks (lingual)	9.5	13.1 *
4-weeks (lingual)	10.	9.4*
Group 3		
Baseline (facial)		
2-weeks (facial)	17.6	13.9*
4-weeks (facial)	17.3	12.3*
Baseline (lingual)		
2-weeks (lingual)	9.9	12.6*
4-weeks (lingual)	9.4	12.1

*Percent reduction values significantly different from zero by I-tailed t-test at 0.05 (all significant except facial PI in Group I at 2 weeks)

Group 2 at p = 0.0434, and Group 3 at p = 0.0005. The mean percentage reductions in the plaque index at D28, for Groups 1,2, and 3 on facial surfaces were 9.0, 8.8, and 17.3, respectively. Group 1 was not significantly different from Group 2, but was significantly less than Group 3 at p = 0.0109.

Plaque Indexfor Lingual Surfaces

The mean percentage reductions in the plaque index at D 14, for Groups 1,2, and 3 on lingual surfaces (Table IV) were 5.7, 9.5, and 9.9, respectively. Group 1 was not significantly different from Group 2 or Group 3 on this measure. The mean percentage reductions in the plaque index at D28, for Groups 1,2, and 3 on lingual surfaces were 8.1, 10.2, and 9.4, respectively. Group 1 was not significantly different from Group 2, but was significantly less than Group 3 at p = 0.0109.

Table V summarizes the group comparisons on facial surfaces by expressing the ratio of the percent reduction of each index in Group 2 and Group 3 compared to Group 1. For example, the ratio of the percent reduction of the bleeding index at D28 in Group 2 compared to Group 1 would be 59.2/30.6 = 1.93, a near two-fold increase in percent reduction. This gives a single number comparison. It can be seen from Table V that the gingival health measures of bleeding index and gingival index range between 1.15 and 1.93 across the two follow-up times. Plaque index ratios were much more variable due to fluctuations in both numerator and denominator values.

Table V
Ratios of Percentage Reduction of Facial I

2-weeks	Group 2/Group I	Group 3/Group I
Bleeding Index	1.36	1.28
Girigival Index	1.51	1.40
Plaque Index	2.25	3.45
4-weeks	**Group 2/Group I**	**Group 3/Group I**
Bleeding Index	1.93	1.65
Gingival Index	1.53	1.15
Plaque Index	0.98	1.92

Discussion

Although it is universally recognized that interproximal cleaning is essential for controlling periodontal disease, many people have difficulty accomplishing this with traditional dental floss. It has been documented that about 30% of the adult population use floss, and even fewer (22%) use it correctly.24 Additionally, when given a preference, most patients choose an alternative device over manual floss.[28-30]

This study shows that the addition of oral irrigation to either manual or power tooth brushing provides significant benefits to oral health through greater reductions in bleeding and gingivitis over traditional brushing and flossing, notably with a near twofold increase in the percent reduction in bleeding in Group 2 compared to Group 1. While oral irrigation studies in the past have allowed subjects who flossed to continue with their regimen, this is the first study to evaluate the use of oral irrigation and brushing compared to a group of subjects that included both brushing and flossing. This finding may be important to individuals who either do not floss, or have significant difficulties flossing. Based on these results, it appears that the manual or power tooth brushing, plus the use of an oral irrigation device once daily with plain water, is as effective as a traditional brushing and flossing routine, and in some cases may provide superior results for reducing bleeding and gingivitis.

The reason oral irrigation is as effective as flossing in this study is not completely understood. Based on previous studies, it is likely related to both the ability of irrigation to reduce subgingival pathogens and to modulate the host response. Cobb and investigators demonstrated via electron microscope that oral irrigation with water reduced periodontal pathogens up to six millimeters, and reduced the fibrin-like network housing the plaque.[9] Likewise, Drisko, *et at.* demonstrated spirochete reduction up to 6 mm.[11] In 1994, Chaves, *et at.* found that oral irrigation with either water or 0.04% chlorhexidine reduced subgingival pathogens over tooth brushing plus 0.12% chlorhexidine rinsing and tooth brushing alone.[7] They noted that even though water irrigation reduced subgingival pathogens, it did not significantly change the measurement of supragingival plaque. At the same time, they found that inflammation was reduced independent of plaque removal.

Chaves, *et at.* further speculated that oral irrigation may produce a change in the host response.[7] In 2000, Cutler, *et al.* demonstrated the host modulatory effect of oral irrigation by showing that daily irrigation with water reduced the gingival crevicular fluid measures of pro-inflammatory mediators IL-13 and PGE_2, while increasing an anti-inflammatory mediatory IL-IO and holding stable IFNy better than routine oral hygiene.[5] Further, Cutler, *et at.* noted that only the addition of irrigation produced this host modulatory change.[5] Tooth brushing alone did not. Interestingly, the reduction in bleeding could not be linked to plaque removal, but rather was correlated to the reduction of IL-~.[5] In 2002, AI-Mubarak, *et al.* found that twice daily water irrigation via a soft subgingival tip (Pik Pocket® subgingival irrigation tip, Waterpik Technologies, Fort Collins, CO) reduced both traditional clinical measures of periodontitis and serum measures of IL-~ and PGE_2 in individuals living with diabetes better than tooth brushing alone.[6]

Oral irrigation has a long history of reducing bleeding and gingivitis independent of plaque removal. While this sounds contradictory, emerging information on the virulence of plaque are beginning to provide answers. Full understanding will only come with further research into the complexities of plaque as a biofilm. Socransky and Haffajee[31] noted that hydrodynamics affect both the physical shear stress and the rate at which nutrients are transported to the surface of plaque, and that these impact the structure and growth of plaque. They also state that modification of the host response affects plaque habitat and the colonization of microbiota.[31] These findings have similarities to a 1988 study by Cobb, *et al.* who found that non-irrigated areas had plaque and debris in fibrin-like mesh, while irrigated sites had little or no fibrin mesh present.[9]

Flossing is a mainstay in the culture of dental professionals. Moving away from traditional devices with concrete methods of removing plaque to products that provide benefits via a host modulatory effect may be difficult. Studies such as this contribute to a healthy professional discourse that paves the road for future research and product development.

The results of this clinical trial support the findings of previous research in that the mechanism by which oral irrigation improves gingival health is not completely understood. A consistent finding in previous research is that the use of an oral irrigator improves bleeding and gingivitis without a direct correlation to a reduction in the amount of plaque, suggesting the disruption of plaque and subsequent removal of endotoxins weakens the pathogenicity of the plaque. Oral healthcare providers are challenged consistently to achieve even 30% patient compliance with flossing,24 making the selection of alternative interdental cleaning devices all the more important. Significant improvements in oral health occurred regardless of toothbrush type, so it is likely that many patients currently using a power toothbrush may get further improvements in oral health by the addition of oral irrigation. The results of this clinical trial indicate that when combined with tooth brushing, oral irrigation is an effective alternative to traditional dental floss for reducing bleeding and gingival inflammation.

Based upon the findings in this study, further research on the long-term effects of irrigation regimens is warranted.

Conclusions

The results of this study reveal the following:

1) Oral irrigation paired with a manual toothbrush was statistically better at reducing bleeding and gingivitis than manual brushing and flossing. Notably, the group utilizing oral irrigation and manual brushing had a near two-fold increase in the percent reduction of bleeding, compared to the group utilizing a manual brush and floss.

2) Oral irrigation paired with a power toothbrush was statistically better at reducing bleeding and better at reducing gingivitis than manual brushing and flossing.

3) Oral irrigation and manual brushing removed plaque as well as manual brushing and flossing on lingual surfaces, while oral irrigation plus power brushing was statistically better than manual brushing and flossing on facial surfaces.

Acknowledgment: We gratefully acknowledge the contributions made by Julie Layton, CDA, Ms. Marian Schmid, and Ms. Diane Thompson to this project. And the authors would like to thank Ms. Carol Jahn for her editorial contributions. This research was supported by Waterpik Technologies.

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