REVIEW ARTICLE

A Husseini DE Slot GA Van der Weijden The efficacy of oral irrigation in addition to a toothbrush on plaque and the clinical parameters of periodontal inflammation: a systematic review

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© 2008 The Authors. Journal compilation © 2008 Blackwell Munksgaard Abstract: Aim: The aim of this review was to systematically review the literature on the adjunctive effect of oral irrigation in addition to toothbrushing on plaque and clinical parameters of periodontal inflammation. Material and Methods: Papers in the MEDLINE-PubMed and Cochrane Central register of Controlled Trials (CENTRAL) databases up to January 2008 were searched to identify appropriate studies. Clinical parameters of periodontal inflammation such as plaque, bleeding, gingivitis and pocket depth, were selected as outcome variables. Results: Independent screening of the titles and abstracts of 809 PubMed and 105 Cochrane papers resulted in seven publications that met the eligibility criteria. Mean values and standard deviations were collected by data extraction. Descriptive comparisons with brushing alone or regular oral hygiene are presented. Conclusion: As an adjunct to brushing, the oral irrigator does not have a beneficial effect in reducing visible plaque. However, there is a positive trend in favour of oral irrigation improving gingivial health over regular oral hygiene or toothbrushing only.

Key words: bleeding; gingivitis; irrigation devices; oral irrigation; oral irrigator; plaque; pocket depth; systematic review

Introduction

Microbial biofilms are common in nature and the oral cavity is an ideal environment for biofilm formation (1). Dental plaque is a bacterial biofilm that consists of complex communities of bacterial species that reside on tooth surfaces or soft tissues and play an important role in oral and dental diseases. Regular removal of the plaque is, therefore, essential and has been the cornerstone of disease prevention (1, 2).

The most widespread means of actively removing plaque is toothbrushing (3–5). The toothbrush, however, does not reach the interproximal surfaces of the teeth as efficiently as it reaches the facial, lingual and occlusal surfaces, and it is incapable of reaching the interproximal areas between adjacent teeth (6, 7). Thus, the removal of plaque from these surfaces is very important because gingivitis and periodontitis are usually more pronounced in the interdental areas than on the oral or facial surfaces in susceptible patients (8). Dental caries also occur more frequently in the interdental region than on oral or facial smooth surfaces (9), and plaque build-up at interproximal sites has been reported to be more acidogenic than in other areas of the mouth (10).

Daily interproximal plaque control is not a common behaviour (11). However, the removal of plaque from interdental surfaces remains an important life-long objective for dental patients. A common problem with all interdental cleaning aids is patient dexterity and motivation. Additional oral hygiene aids have been developed in an attempt to augment the effect of toothbrushing on reducing interdental plaque (12).

The oral irrigator (OI) was introduced in 1962. This device has been demonstrated to be safe (13, 14), and it is likely to provide a particular benefit for gingival health to a large part of the general public that does not clean the interproximal space on a regular basis (11). The adjunctive aid of the OI is designed to remove plaque and soft debris through the mechanical action of a jet stream of water. Oral irrigator devices can also be used with antimicrobial agents (15). Patients report that the OI facilitates the removal of food debris in posterior areas, especially in cases of fixed bridges or orthodontic appliances, when the proper use of interdental cleaning devices is difficult (16).

Since its introduction, the OI has at times been a popular device (17). However, there has also been considerable controversy regarding the appropriate use and efficacy of this instrument (17, 18). Studies using OI have reported both positive (19–22) and negative results (23, 24) in terms of dental health and plaque. This inconsistency causes confusion about the efficacy of the OI. The aim of this systematic review of the existing literature was to evaluate the effectiveness of oral water irrigation as an adjunct to toothbrushing on plaque and clinical parameters of periodontal inflammation in comparison with toothbrushing alone or regular oral hygiene.

Materials and methods

Search strategy

Two internet sources were selected to search for papers satisfying the study purpose: MEDLINE-PubMed (The National Library of Medicine, Washington DC, USA) and CEN-TRAL (the Cochrane Central register of controlled trials); both sources were searched for articles from 1965 through January 2008. The search was inclusive for any study that evaluated the effect of oral irrigation in addition to toothbrushing.

The following terms were used as the search strategies: <u>Intervention</u>: < [textwords] oral irrigation OR oral irrigator OR oral irrigation jet OR water jet irrigator OR dental water jet OR water pick OR water pik OR waterpik OR perio pik OR pick pocket OR pickpocket OR pik pocket OR monojet oral irrigator OR subgingival irrigation OR subgingival tip OR dental irrigator OR dental irrigation>

AND

<u>Outcome:</u> <[textwords] cytotoxine OR papillary bleeding index OR sulcus bleeding OR dental deposit* OR gingival pocket OR plaque removal OR bleeding on probing OR gingival bleeding OR pocket depth OR gingival inflammation OR gingival diseas* OR plaque index OR periodontal pocket OR gingival index OR gingivitis OR dental plaque OR dental deposits OR dental deposit OR periodontitis OR periodontal diseas* OR dental caries OR caries OR plaque OR bacteria OR [MesH] Periodontal Diseases>

The eligibility criteria were:

- Randomized controlled clinical trials (RCTs)
- Controlled clinical trials (CCTs)
- Conducted in humans:
 - good general health (no systemic disorders)
 - ≥ 18 years of age
- No orthodontic appliances
- Intervention:
 - supragingival use of the OI
 - irrigation with water
 - used as an adjunct to tooth brushing or regular oral hygiene (ROH)
 - · performed by subject
- No use of subgingival irrigation tip
- Control group: toothbrushing only or ROH
- Evaluation parameters: plaque/bleeding/gingivitis/pocket depth
- Experimental period of ≥ 4 weeks (25)

Only papers written in English were accepted. Case reports, letters and narrative or historical reviews were not included in the search. Papers without abstracts but with titles related to the objectives of this review were selected, so the full text could be screened for eligibility.

Screening and selection

The papers were screened independently by two reviewers (AH & GAW), first by title and abstract to eliminate the studies that were not relevant. Then, full-text papers were identified that fulfilled the eligibility criteria for inclusion according to the study aim (AH, DES, GAW). After the search, all reference lists of selected studies were screened for additional papers that might meet the eligibility criteria of the study. Any disagreement between the reviewers was resolved with additional discussion.

Assessment of heterogeneity

The heterogeneity of the primary outcome across studies was evaluated according to the following factors:

- Study design and evaluation period
- Number, age and range of subjects
- Medical and periodontal status of subjects
- Intervention and control
- Prophylaxis and Oral Hygiene Instruction (OHI)
- Industry funding

Quality assessment

The methodological study quality was evaluated based upon the following aspects:

- Method of randomization
- Blindness of examiners
- Number of subjects lost to follow-up
- Studied parameters

Data extraction

From the papers that met the study criteria, data were processed for analysis. Data were extracted with regard to the effectiveness of self-performed OI in comparison with toothbrushing only or ROH. The three reviewers (AH, DES, GAW) extracted mean values and standard deviations (SD). Some of the studies provided standard errors (SE) of the mean; SD was calculated by the reviewers based on the sample size.

Data analysis

After a preliminary evaluation of the selected papers, it was clear that considerable heterogeneity was present in the study

designs, characteristics, outcome variables and results. Therefore, it was not possible to perform a valid quantitative analysis of the data and subsequent meta-analysis. Instead, a descriptive review of the data will be presented.

Results

Search and selection results

The PubMed search resulted in 809 citations and the Cochrane search in 105 citations (Table 1). After removing duplicate papers found in both searches, 813 titles and abstracts

Table 1. Search and selection results

Selection	PubMed	Cochrane	Identical
Search	809	105	101
Excluded by title and abstract Selected papers for full reading Excluded after full reading (Table 2)	7	86 27 17	
Included after full reading		10	
data presentation (Table 2) Final selection for data extraction		7	

Table 2. Overview of the studies that were excluded

Reason for rejection	Author(s), (year)
Evaluation period <4 weeks	Wheatcroft & Sciantarelli 1974 (26), Gupta <i>et al.</i> 1973 (27), Tanaka <i>et al.</i> 1968(28), Lobene <i>et al.</i> 1972(19)
Narrative review	Watt 2001 (29), Venneri 1997 (30), O'Hehir 1997 (31), Dunkin 1972 (32)
No brushing group	Ciancio <i>et al.</i> 1989 (33), Macaulay & Newman 1986 (34), Tempel <i>et al.</i> 1975 (35)
Only one irrigation episode	Fine & Baumhammers 1970 (36), Clynes & Wilderman 1970 (37)
Irrigation performed by professional	Toto <i>et al.</i> 1969 (38)
Not as an adjunct to tooth brushing	Covin <i>et al.</i> 1973 (39)
Not conducted in humans	Reddy <i>et al.</i> 1985 (40)
In vitro study	Selting <i>et al.</i> 1972 (41)
Poster presentation	Hoover <i>et al</i> .1968 (42)
Insufficient data presentation	Chaves <i>et al.</i> 1994 (43), O'Hehir 1994 (44), Boyd <i>et al</i> .1985 (45)

remained. Screening the titles and abstracts initially resulted in 27 full-text papers. In total, 17 studies were excluded, and the reasons are given in Table 2. Further, three more papers (43–45) were excluded because of insufficient data on the clinical parameters (Table 2). Searching the reference lists of the selected studies resulted in no new papers. Consequently, seven studies were identified as eligible for inclusion in this review according to defined criteria for study design, participants, intervention and outcome.

Outcome results

Assessment of heterogeneity

An overview of the papers and study characteristics is presented in Table 3.

Study design and evaluation period

Six papers were RCTs (II, III, IV, V, VI, VII), and one paper was a CCT (I). One study had a cross-over design (IV), while the other six employed a parallel design. The evaluation period of the selected studies varied from 8 weeks (III) to 7 months (IV, VI). For studies that presented intermediate assessments of OI use, the baseline and final evaluations were used for this review. Paper VII had a total evaluation period of 6 months; subjects returned 3 months after baseline examination for re-examination and full-mouth professional mechanical oral hygiene care. For this reason, the intermediate data from the third-month examination were used as end data. Study IV did not report overall data; for this reason, the data from the first phase of the cross-over study were used. Study VI was a multi-centre study; all four involved centres were in different countries.

Medical and periodontal status of subjects

Patients with systemic disorders were excluded in three papers (I, II, VI). One paper (III) explicitly included subjects that were in a good general health and excluded subjects with systemic disorders that would have interfered with gingival evaluation. Pregnancy was an exclusion criterion in four studies (I, II, VI, VII). One paper (VII) excluded patients with oral lesions or systematically related gingival enlargement. Two studies included patients with naturally occurring gingivitis (I, III). One paper included patients who exhibited a high degree of oral hygiene and whose periodontal tissue appeared relatively normal (IV). Two other studies selected patients with periodontitis in a maintenance care phase (II, VI).

Study II included subjects with a minimum of two quadrants, with pocket probing depth of ≥ 5 mm and bleeding upon probing. An inclusion criterion for paper VII was a gingival index >1 at a minimum of six sites out of a total of 18 sites of the Ramfjord periodontal disease indices (Ramfjord 1959). None of the papers report any information about the smoking behaviour of the subjects.

Intervention and control

Normal oral hygiene (I, II,) is referred to in this review as the control group (ROH), meaning the subjects' habitual use of oral hygiene products. Four (I, II, V, VI) of the seven studies compared OI as an adjunct to ROH. Three papers (III, IV, VII) compared the OI to manual brushing. Study VII compared OI also with powered brushing. In study IV, a rubber interdental stimulator was used as an adjunct in both groups (intervention and control). The WaterPik® Teledyne, Fort Collins, CO, USA was the most frequent OI used (I, II, VI). One study (I) used the WaterPik[®] 20, and two studies the WaterPik[®] 30E (II, VI); study IV did not mention the specific type. Other brands were only used once: Broxojet 3007 Broxo S.A., Geneva, Switserland (VII), Braun Oral-B[®] Oxyjet[®] MD 15 Kronenberg, Germany (III), and Ap2 Aqua Pulse (V). In three studies, subjects irrigated with 500 ml H₂O once daily (I, II, VI). In study III, subjects irrigated with 600 ml H₂O once daily. In study VII, the frequency of irrigation was two times per day, but no information about the amount of H₂O that was used by the subjects was provided.

Prophylaxis and oral hygiene instruction

In four studies (I, II, IV, V), all participants received a complete oral prophylaxis at baseline. OHI for brushing and OI were given in three studies (III, IV, VII). Subjects were only instructed in the use of the OI devices at baseline in four studies (I, II, V, VI). Subjects in study VII were called by phone every 2 weeks to reinforce OHI. In all studies, the interventions were performed in conjunction with unsupervised oral hygiene.

Industry funding

The Teledyne WaterPik[®] Company supported three papers (I, II, VI). Two other companies support one study each – a General Electric Company Grant supported study V, and Xouth, Inc., (Lancaster, PA, USA) partially funded study VII. Study III researched the Braun MD 15, and a co-author was the study manager of the Clinical Research Oral Care, Braun GmbH, Kronberg, Germany. Study IV did not report industry funding.

No	Author (year)	Title	Design & evaluation period	No. of subjects, gender, age	Comparison	Conclusion
_	Flemmig <i>et al.</i> (1990) (46)	Supragingival Irrigation with 0.06% Chlorhexidine in naturally occurring gingivitis I. 6 month clinical observation	CCT Parallel 6 Months	109 subjects ♀? ♂? Range: ? Mean age: 36.6 years	ROH + OI ROH	Irrigation with H ₂ O had significantly less clinical benefits than CHX irrigation
=	Flemmig <i>et al.</i> (1995) (47)	Adjunctive supragingival irrigation with acetylsalicyclic acid in periodontal supportive therapy.	CCT Parallel 6 Months	37 subjects ♀? ♂? Range: 19–75 years Mean age: 47 ◇	ROH + OI ROH	Supragingival irrigation with ASA or H ₂ O in addition to regular oral hygiene appears to be a beneficial adjunct
⊨	Frascella <i>et al.</i> (2000) (11)	A randomized, clinical evaluation of the safety and efficacy of a novel oral irrigator.	RCT Parallel 8 Weeks	64 subjects ♀ 42 ♂ 22 Range:18–61 years Mean age: 39.5 ◇	MB + OI MB	No statistically significant difference. The use of the irrigator in conjunction with manual brushing is safe, reduces plaque and improves gingival health
2	Hoover <i>et al.</i> (1971) (48)	The comparative effectiveness of a pulsating oral irrigator as an adjunct to maintaining oral health	RCT Cross over 7 Months	48 subjects ♀?♂? Range:? Mean age:?	MB + RIS + OI MB + RIS	The groups incorporating the oral irrigator into their oral hygiene routine significantly reduced the periodontal index, as well as the amount of plaque and calculus accumulation over a 3-month period as compared with those using the toothbrush and interdental stimulator without the oral irrigator
>	Meklas <i>et al.</i> (1972) (49)	Investigation of the safety and effectiveness of an oral irrigating device	RCT Parallel 7 Months	109 subjects ♀?♂? Range:? Mean age:?	ROH + OI ROH	Irrigator is safe when used according to manufacturer's instructions. Although the calculus scores were lower for the irrigation group on the last two examinations and the gingivitis score were lower on all examinations over seven-months, there were no statistically significant differences between the group using the test oral irrigator and the control group
⋝	Newman <i>et al.</i> (1994) (16)	Effectiveness of adjunctive irrigation in early periodontitis: multi-centre evaluation.	CCT Parallel 6 Months Multi Centre	115 subjects ♀?♂? Range:18–75 years Mean age:46.5 ◇	ROH + OI ROH	This study demonstrated that adjunctive supragingival irrigation with H ₂ O can provide meaningful clinical outcomes for patients in maintenance phase
₹	Walsh <i>et al.</i> (1989) (23)	Comparison of manual and power tooth brushing, with and without adjunctive oral irrigation, for controlling plaque and gingivitis	RCT Parallel 3 Months	108 subjects ♀?♂? Range:18–65 years Mean age: 41.5 ◇	MB + OI PB + OI MB BP	The results of all interventions were equally effective in reducing plaque, gingivitis, bleeding and number of deep pockets

Table 3. Overview of the studies processed for data extraction

Quality assessment

Method of randomization

Six studies randomly assigned the subjects to the different groups (II, III, IV, V, VI, VII). Study VI balanced subjects by sex and subsequently randomly allocated them to the groups. In one study, subjects were allocated to groups based on their consecutive order of entry into the study (VII). In this review, study I is depicted as a CCT. According to the paper, the subjects were assigned to one of the treatment groups after balancing for sex and a Gingival Index ≥ 2 ; however, there was no mention of randomization (I).

Blindness of examiners

The examiners in five studies were blinded to the intervention assignment (I, II, III, VI, VII). Study VII also carefully cautioned the subjects not to discuss their oral hygiene method with the examiner. In two studies, it was not stated whether the examiner was blinded (IV, V).

Number of subjects lost to follow-up

Most studies reported loss to follow-up (I, II, III, IV, VI). The reasons were sometimes mentioned (I, II, III, VI); however, no predominant reasons were found. Complications arising from study participation were not a reason for drop out. Reasons that were most frequently cited were absence from the (final) examination (I, II, III), protocol violation (III), tooth staining (I), pregnancy (I), personal inconvenience (III) and discontinuation of the use of the OI (III). Two studies did not report any information about the number of subjects lost to follow-up (V, VII).

Studied parameters

In Table 4, the various indices of plaque and parameters of periodontal inflammation from the selected papers are summarized and presented. Table 5 shows the result from the data extraction, and Table 6 shows the results from the descriptive analysis.

Study outcome

Within groups (Table 5)

Plaque

In study III, significant improvements were observed between baseline and the end of the study for only the OI group. Study

Table 4. Used indices

Plaque index Plaque Index Silness & Löe (1964) Turesky-Gilmore-Gickman Index (1970) Own indices	I, II, VI, VII III IV, V
Bleeding index Bleeding on probing The Angular Bleeding Index Weijden (1994)	I, II, VI, VII III
Gingival index Modified Gingival Index Löe (1967) Gingival Index Löe & Silness (1963) Gingival Index Lobene (1986) Modified Periodontal Index Russel (1967) Own index	I, II, VI VII III V IV
Probing Pocket depth	I, II, VI, VII

IV showed significant improvement for both groups, OI and ROH. The other five studies (I, II, V, VI, VII) did not present significant data on changes between baseline and the end of the study (Table 5a).

Periodontal parameters

Bleeding

Study III reported a significant reduction of bleeding from baseline to the end of the study in both the OI and manual brushing groups. Study VII reported a significant reduction in bleeding for only the group assigned to OI as an adjunct to manual brushing (Table 5b).

Gingivitis

One study (I) found a significant difference between baseline – end scores for the OI group. Another study (III) reported significant differences between baseline and endscore intervention for the manual brushing group (Table 5c). Probing pocket depth

Pocket depth reduction from baseline was observed in four studies, but none of the results were significant (I, II, VI, VII) (Table 5d).

Between groups (Table 6)

None of the selected studies showed a significant difference between the toothbrush plus OI and the toothbrush only group. There are some (I, II, VI) significant differences in favour of the OI compared with ROH on plaque and the clinical parameters of periodontitis (Table 6). With respect to plaque, no significant differences were observed. Three studies (I, II, VI) showed significant reductions in bleeding for the OI group as compared

Table 5. Results (a) Plaque index (b) Bleeding index (c) Gingival index (d) Probing pocket depth

			Mean (SD)		
No.	Index	Intervention	Baseline	End	Difference
(a) 	Silness & Löe (1964)	ROH + OI ROH	1.03 (0.44◇) 1.12 (0.44◇)	0.75 0.75	-0.28
	Silness & Löe (1964)	ROH + OI ROH	0.67 [0.61; 0.75] ■ 0.65 [0.61; 0.67] ■	? ?	? ?
	MPI Turesky-Gilmore-Gickman (1970)	MB + OI MB	2.62 (0.46) 2.66 (0.34)	2.46 (0.51)* 2.64 (0.45)	-0.16
IV	Plaque index Hoover <i>et al.</i> (1971)	ROH + RIS + OI ROH + RIS	0 0	0.232* 0.279*	+0.232 +0.279
V	Meklas (1972)	ROH + OI ROH	$\begin{array}{c} \ominus ? \\ \ominus ? \end{array}$	2.54 (2.37) 3.20 (3.42)	+2.54
VI	Silness & Löe (1964)	ROH + OI ROH	0.97 1.06	0.91 0.97	-0.06 -0.11
VII	Silness & Löe (1964)	MB + OI PB + OI MB BP	1.3 (0.6) 1.4 (0.7) 1.3 (0.7) 1.5 (0.7)	1.0 (0.7) 1.0 (0.7) 1.0 (0.7) 0.9 (0.7)	-0.3
(b)	Bleeding on probing	ROH + OI ROH	37.4% (18.37◇) 36.3% (14.83◇)	23.6% 31.1%	-13.8% ◇ ‡ -5.2% ◇
	Bleeding on probing	ROH + OI ROH	0.35 [0.31; 0.41] ■ 0.24 [0.21; 0.31] ■	? ?	? ‡ ?
	Angular Bleeding Index (v/d Weijden <i>et al.</i> 1994)	MB + OI MB	58.8% (13.6) 53.5% (15.1)	43.6% (18.2)* 42.6% (19.1)*	-15.2%
VI	Bleeding on probing	ROH + OI ROH	0.35 0.31	0.27 0.34	-0.08 ‡ +0.03
VII	Bleeding on probing	MB + OI PB + OI MB BP	46% (13) 46% (19) 38% (18) 49% (16)	34%(17)* 44% (20) 36% (18) 39% (20)	-12%

with the ROH group. When observing visual signs of gingival inflammation, three studies (I, II, VI) found a significant additional effect of OI as adjunct to ROH. Two of the four studies, II and VI showed a significant reduction of the probing depth as a result of OI as an adjunct to toothbrushing. Study IV does not provide appropriate data for comparisons between groups. For study VII, it was not clear if there was a significant difference between the groups after 3 months.

Discussion

Evidence-based dentistry is the integration of clinical expertise, patient values, and the best evidence into the decision-making process for patient care. The best evidence is usually found in clinically relevant research that has been conducted using sound methodology (50). A systematic review carries weight because of its high level of evidence. This systematic assessment of the available literature for the effects of healthcare interventions is intended to help the professional in this process (51). There exist a wide variety of opinions regarding the 'true value' of adjunctive OI (17). The aim of the present review was to systematically assess the effect of OI in addition to toothbrushing on plaque build up and parameters of periodontal inflammation.

The selected studies did not provide sufficient data to perform a meta-analysis. Descriptive data show that there is no benefit above and beyond toothbrushing on removing plaque. On the other hand, based on the individual papers, a trend was observed that indicated a beneficial adjunctive effect of OI on the

			Mean (SD)		
No.	Index	Intervention	Baseline	End	Difference
(c) 	Modified Gingival Index Löe (1967)	ROH + OI ROH	0.51 (0.29◊) 0.54 (0.30◊)	0.39* 0.51	-0.12 ◇ ‡ -0.03 ◇
11	Modified Gingival Index Löe (1967)	ROH + OI ROH	1.20 [1.16; 1.40] ■ 1.12 [1.10; 1.18] ■	? ?	- ? ‡ - ?
111	Lobene <i>et al.</i> (1986)	MB + OI MB	1.72 (0.47) 1.66 (0.58)	1.53 (0.52) 1.45 (0.58)*	-0.19
IV	Periodontal index Hoover& Robinson (1971)	ROH + RIS + OI ROH + RIS	0.207 0.232	0.215 0.281	+0.008 +0.049
V	Gingivitis score Russel (1967)	ROH + OI ROH	1.45 (2.06) 2.32 (3.35)	3.70 (3.37) 4.69 (3.26)	+2.25
VI	Modified Gingival Index Löe (1967)	ROH + OI ROH	1.19 1.24	0.97 1.28	-0.22 ‡ +0.04
VII	Gingival Index Silness & Löe (1963)	MB + OI PB + OI MB PB	1.4 (0.5) 1.4 (0.4) 1.3 (0.4) 1.3 (0.5)	1.1 (0.5) 1.2 (0.5) 1.2 (0.4) 1.2 (0.5)	-0.3
(d)		ROH + OI ROH	3.2 (0.44◇) 3.0 (0.30◇)	3.0 3.0	-0.2
11		ROH + OI ROH	2.29 [2.20; 2.39] ■ 2.32 [2.27; 2.45] ■	? ?	? ‡ ?
VI		ROH + OI ROH	2.20 2.23	2.09 2.24	-0.11‡ -0.01
VII		MB + OI PB + OI MB BP	$ar{X}$ 2.7(0.65) 2.7 (0.6) $ar{X}$ 2.7(0.65) 2.7 (0.6)	? ? ?	? ? ? ?

Table 5. (Continued)

 \blacksquare = median [CI]; CI 95% = confidence interval; * = significant baseline – end; \ddagger = significant better than brushing only; \bar{X} = mean. For additional abbreviations, see Table 3.

Table 6.	Overview of the resu	Its of the toothbrush	and oral irrigatior	n group in comparison	with the toothbrush or	ily or regular oral
hygiene	group					

Author(s)	Plaque score	Bleeding score	Gingival score	Pocket depth	Comparison
	0	0	0		Toothbrush only
IV	?		?		Toothbrush only
VII	0	0	0	?	Toothbrush only
I	0	+	+	0	Regular oral hygiene
11	0	+	+	+	Regular oral hygiene
V	0		0		Regular oral hygiene
VI	0	+	+	+	Regular oral hygiene

+, significant difference in favour of test group; \mathbf{O} , no significant difference; \Box , no data available; ?, unknown.

Gingival Index (GI) (I, II, VI), bleeding score (I, II, VI) and pocket depth (II, VI). With respect to study IV, the periodontal index of the toothbrush only group (control group) deteriorated in time, while there was improvement in the OI group. Consequently, the difference between the OI group and the toothbrush only group became large, and the results favoured the OI group. This positive effect on the magnitude of the observed difference was a phenomenon seen in both phases of the cross-over study. This observation is surprising because a Hawthorne effect would normally result in an improvement in the control group.

Indices

Plaque reduction is a prerequisite for an oral hygiene device to be considered valuable (17). The selected papers for this review report no statistically significant reduction in plaque when the OI was used as adjunct to toothbrushing compared with toothbrushing only (Table 5). Study VII did mention a statistically significant reduction in 'visible' plaque (score 2 or 3 of the Silness & Loë plaque index (52)) between the baseline and a 3-month examination for all the groups. Despite a lack of effect on the plaque index, studies did find a significant effect on the bleeding index (I, II, VI) and the GI (I, II, VI). The mechanisms of action underlying these clinical changes in the absence of a clear effect on plaque are not understood. Different hypotheses have been put forward by the authors to explain the results. One of the hypotheses is that when patients with gingivitis perform supragingival irrigation on a daily basis, the populations of key pathogens (and their associated pathogenic effect) may be altered, reducing gingival inflammation (47). There is also the possibility that H_2O pulsations may alter the specific host-microbial interaction in the subgingival environment and that inflammation is reduced independent of plaque removal (43). Another possibility is that the beneficial action of OI is at least partly because of the removal of food deposits and other debris, flushing away of loosely adherent plaque, removing bacterial cells, interfering with plaque maturation and stimulating the immune response (11). Other explanations could be a mechanical stimulation of the gingiva or a combination of these reported factors (11, 46). Irrigation may reduce the thickness of plaque, which may not be easily detectable using 2-dimensional scoring systems (53). This may be the reason for an absence of an effect on plaque but a positive effect on gingival inflammation (Tables 5a and 6).

Irrigation liquids

The OI can also be used to apply antimicrobial agents to chemically control plaque (15, 46). Adjunctive OI with antimicrobial agents is effective in reducing clinical (33, 46, 53, 54) and microbiological (53) parameters in individuals with gingivitis. The effect of supragingival irrigation with chlorhexidine (CHX) on the development of plaque and gingivitis has been studied using an experimental gingivitis model without

mechanical plaque control (46). The use of CHX at low concentrations (e.g. 0.06%) led to better plaque inhibition and had an anti-inflammatory effect (15, 46). The application of CHX by an OI was more effective than rinsing with CHX at the same concentrations on naturally occurring gingivitis during an 8-week period (15, 46). The use of an OI tip was beyond the scope of this review, which specifically addressed 'supra'-gingival plaque control.

Subgingival irrigation

Irrigation devices may increase the delivery of fluid beneath the gingival margin (46). Greater penetration of a solution into the periodontal pockets is achieved by patient-applied supragingival irrigation as compared with mouth rinsing (47). Studies that evaluated the ability of supragingival irrigation to project an aqueous solution (H₂O or medicinal fluids) subgingivally determined that supragingival irrigation with a standard irrigation tip was capable of delivering H₂O or a medicinal fluid 3 mm subgingivally or to approximately half the probing depth in a 6-mm pocket (55, 56). Two studies demonstrated that H₂O irrigation had little effect on the composition of the subgingival flora in sites with pocket probing depth of 4 mm or less (57, 58). An accessory to an OI device is the Pik Pocket[®] subgingival irrigation tip (WaterPik Technologies, Fort Collins, CO, USA), which facilitated subgingival penetration of irrigants to 90% of 6-mm pockets' depths when placed 1 mm subgingivally (59).

Hydrokinetics and irrigation forces

Various types of OI devices (both pulsating and non-pulsating) have been introduced to the general public. Hydrokinetic and irrigation force devices used for supragingival irrigation usually provide a pulsating stream of H₂O that incorporates a compression and interpulse decompression phase. Continuous H₂O flow causes constant tissue compression and impedes the removal of contaminants. It has thus been reported that a decompression phase should be included to facilitate displacement of debris and bacteria. The pulsating, hydrodynamic forces produced by irrigators can rinse away food debris from interdental spaces and plaque-retentive areas (60). Supragingival irrigation forces of 80 to 90 psi (Pounds per Square Inch) can generally be tolerated without untoward effects (45, 61). As demonstrated by scanning electron micrographs of biopsies of human gingival tissues, a 60 psi irrigation force induced no epithelial micro-ulceration or alteration of cell morphology (14).

Bacteraemia and safety

Supragingival irrigation applies considerable force to the gingival tissues. Given the collective evidence, it appears that irrigation is safe for healthy patients. Irrigation had the potential to induce a bacteraemia comparable to what is found after brushing (62, 63), flossing (64, 65), scaling and root planing (66), and chewing (67). Furthermore, daily marginal irrigation for 3 months did not increase the risk of developing a bacteraemia during a maintenance program following periodontal therapy (68). However, clinicians should exercise caution regarding instructions or advice for home irrigation for individuals at risk for endocarditis because no specific information is available concerning the degree of risk that may be created by home irrigation in this population.

In conclusion, this review examined the effectiveness of OI as an adjunct to toothbrushing. The evidence suggests that the use of OI does not have a beneficial effect on reducing plaque scores. However, there is evidence that suggests a positive tendency towards improved gingival health in favour of the OI when compared with ROH. These conclusions are based upon the preponderance of published studies.

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