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The efficacy of dental floss in addition to a toothbrush on plaque and parameters of gingival inflammation: a systematic review

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Abstract: *Objectives:* The aim of this study was to assess systematically the adjunctive effect of both flossing and toothbrushing versus toothbrushing alone on plaque and gingivitis. *Materials:* The MEDLINE and Cochrane Central register of Controlled Trials (CENTRAL) databases were searched through December 2007 to identify appropriate studies. The variables of plaque and gingivitis were selected as outcomes. *Results:* Independent screening of titles and abstracts of 1166 MEDLINE–Pubmed and 187 Cochrane papers resulted in 11 publications that met the eligibility criteria. Mean values and SD were collected by data extraction. Descriptive comparisons are presented for brushing alone or brushing and flossing. A greater part of the studies did not show a benefit for floss on plaque and clinical parameters of gingivitis. A meta-analysis was performed for the plaque index and gingival index. *Conclusions:* The dental professional should determine, on an individual patient basis, whether high-quality flossing is an achievable goal. In light of the results of this comprehensive literature search and critical analysis, it is concluded that a routine instruction to use floss is not supported by scientific evidence.

Key words: bleeding; dental floss; dental tape; gingivitis; plaque; systematic review

Introduction

It is generally accepted that bacterial plaque is an important aetiological factor of periodontal diseases (1). Despite recent advances in oral chemotherapeutics, mechanical removal of

plaque remains the primary method for controlling supra-gingival accumulations (2, 3).

The most common method of mechanical plaque control is toothbrushing. Toothbrushing alone, however, does not reach the interproximal areas of the dentition, which means that part of the dentition is left unclean. The interdental areas, especially the posterior, are the least accessible (3, 4). For this reason, soft and/or hard deposits accumulate in the space between teeth in almost all patients (5). Periodontal and gingival lesions are predominantly observed at these sites (6). As the interproximal areas of the dentition are also frequently affected by caries, interproximal cleaning represents an important aspect of oral self-care (7). Patients should therefore resort to additional techniques to toothbrushing.

A wide variety of interdental cleaning devices are available. For the most part, the most appropriate interdental aid depends on the size and shape of the interdental space, as well as the morphology of the proximal tooth surface. Also, the level of dexterity and ability of the patient to use a hygiene aid should be taken into account (8). As a method to remove interproximal plaque, flossing has received the most attention. However, the difficulty in flossing probably makes this technique less than universal in its application (9).

Over the years, it has been generally accepted that dental floss has a positive effect on removing plaque (10, 11). The American Dental Association (ADA) even reports that up to 80% of plaque may be removed by this method (12). Several reviews have been conducted on the efficacy of manual flossing, flossing aids and devices and other interdental cleansing aids (3, 13–15). However, few reviews are systematic and none of them has conducted a meta-analysis (3). Also, a limited number of studies provide data on the effectiveness of flossing and toothbrushing compared to toothbrushing alone. Many studies compare floss with another interdental aid (2, 16–22). Warren *et al.* wrote that studies that have compared flossing with toothbrushing have found that their combined use produces no clear benefit. Jahn stated that practitioners often perceive flossing as superior to other methods of interdental cleaning, while research has not proven this. Additionally, a recent review showed that self-flossing has no effect on reducing caries risk (23).

The aim of this systematic review was to establish, on the basis of existing literature, the effectiveness of dental floss as an interdental aid in combination with toothbrushing on plaque and clinical inflammatory symptoms of periodontal disease in adults. Eligible studies provided a test group using dental floss as an adjunct to toothbrushing and a control group using toothbrushing only.

Materials and methods

Focused question

What is the effect of the use of dental floss in adult patients as an adjunct to toothbrushing compared to toothbrushing alone on plaque and the clinical parameters of periodontal inflammation?

Search strategy

Two internet sources of evidence were used to search for appropriate papers satisfying the study purpose: the National Library of Medicine, Washington, DC (MEDLINE–PubMed) and the Cochrane Central register of Controlled Trails (CENTRAL). This search included any study that evaluated the effect of dental floss in addition to toothbrushing. Reference lists of potentially relevant studies and review papers were also searched. The databases were searched up to and including December 2007 using the following terms for the search strategy:

Intervention

([MeSH Terms] ‘Home Care Dental Devices’ OR [Text Words] Floss OR Dental floss OR Flossing OR Tape OR Dental tape OR Superfloss OR Ultrafloss OR Interdental cleaning devices OR Interproximal cleaning devices OR Interspace cleaning devices.)

AND

Outcome

([MeSH Terms] Periodontal Diseases OR [Text Words] Gingivitis OR Periodontitis OR Gingival Pocket OR Periodontal Pocket OR Gingival Inflammation OR Gingival Disease* OR Periodontal Disease* OR Bleeding on Probing OR Papillary Bleeding Index (PBI) OR Gingival Bleeding OR Bleeding Index OR Plaque Removal OR Plaque Index OR Dental Plaque OR Plaque OR Removal OR Interdental Plaque OR Interproximal Plaque OR Dental Deposit*.)

Eligibility criteria

At first, titles and abstracts resulting from the search as described above were screened independently by two reviewers (CEB and GAW). Subsequently, full-text papers were screened and selected (CEB, DES and GAW). The following eligibility criteria were taken into account:

- Randomized Controlled Clinical Trails.
- Controlled Clinical Trials.
- Subject ≥ 18 years of age in good general health.
- Clinical parameters: gingivitis, plaque and bleeding.
- Intervention: dental flossing and manual toothbrushing.
- Control group: manual toothbrushing only.
- Interproximal sites measured.
- Duration of ≥ 4 weeks (24).
- No orthodontic appliances.
- In human patients.

Only studies written in English language were accepted. Case reports, letters and historical reviews were excluded from the search. Studies without abstracts but whose titles suggested that they could be related to the objectives of this review were also selected, so the full text could be screened for eligibility. Any disagreements between the reviewers were resolved by discussion.

Assessment of heterogeneity

Factors that were recorded to evaluate the heterogeneity of the primary outcome across studies were as follows:

- Study design and evaluation period.
- Number, age and range of subjects.
- Intervention type of floss and study funding.
- Prophylaxis, oral hygiene instruction.
- Indices and parameters of periodontal disease.

Quality assessment

The methodological study quality was evaluated based on the following parameters:

- Method of randomization.
- Blindness of examiners.
- Completeness of follow-up.

Statistical analyses

Data extraction

From the papers that met the above criteria, data were extracted with regard to the effectiveness of self-performed interdental plaque removal using a toothbrush and floss in comparison to using a toothbrush alone (CEB and DES). Mean values and SD were obtained from the text. Some of the studies provided SE of the mean. SD were calculated by the authors of this review based on the sample size.

Data analysis

After a preliminary evaluation of the selected papers, considerable heterogeneity in the study design, characteristics, outcome variables and results was observed. For the selected studies, only baseline data and end-trial assessments were available. Consequently, it was not possible to perform a meta-analysis of the differences because the SD of the differences was not provided and could not be calculated. Therefore, the data for baseline and end-trials were presented separately. An analysis was performed for both time points. Where appropriate, a meta-analysis was performed, and weighted mean differences (WMD) were calculated by means of the Review Manager 4.2 (Review Manager (RevMan) [computer program]. Version 4.2 for windows. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2003.) software of the Cochrane Collaboration using a 'random effect' model. As a summary, a descriptive manner of data presentation is used.

Results

Search results

The MEDLINE search resulted in 1166 papers. The Cochrane search resulted in 187 papers, which provide 23 additional papers to the MEDLINE search (Table 1). The screening potentially resulted in 36 full-text articles. After a complete reading, 26 studies were excluded. The reasons for exclusion are explained in Table 2. Study XI was taken as an additional paper from the reference lists. The remaining 11 articles that fulfilled the selection criteria were processed for data extraction.

Assessment of heterogeneity

After a preliminary evaluation of the selected papers, considerable heterogeneity was observed in the study design, characteristics and outcome variables. The number, gender

Table 1. Search and selection results

Selection	PubMed	Cochrane	Identical
Search	1166	187	164
Excluded based on title and abstract		1153	
Selected papers for full reading		36	
Excluded after full reading (Table 2)		26	
Included after full reading		10	
Included from reference list		1	
Final selection for data extraction		11	

Table 2. Overview of the studies that were excluded after reading the full paper and reason for exclusion

References	Reason for rejection
Terezhalmay <i>et al.</i> (25)	Single use of floss
Bellamy <i>et al.</i> (26)	No plaque or bleeding index
Sjögren <i>et al.</i> (27)	No plaque or bleeding index
Caton <i>et al.</i> (28)	No flossing group
No authors listed (29)	Not retrievable
Graves <i>et al.</i> (30)	Duration < 4 weeks
Petersen (31)	No separate groups
Svatun <i>et al.</i> (32)	No controlled flossing group
Mallat <i>et al.</i> (33)	No results of flossing
Kleber and Putt (34)	No brushing-only group
Smith <i>et al.</i> (35)	No brushing-only group
Bouwisma <i>et al.</i> (36)	No brushing-only group
Spindel and Person (37)	No brushing-only group
Mauriello <i>et al.</i> (38)	Insufficient data presentation
Seto <i>et al.</i> (39)	No brushing-only group
Lobene <i>et al.</i> (40)	Insufficient data presentation
Abelson (41)	No brushing-only group
Reitman <i>et al.</i> (42)	Duration was not ≥ 4 weeks
Wright <i>et al.</i> (43)	No plaque or bleeding index
Schmid <i>et al.</i> (44)	No flossing adjunct to brushing group
French (45)	No brushing-only group
Garter <i>et al.</i> (46)	Not retrievable
Bergenholtz <i>et al.</i> (47)	Insufficient data presentation
Elliott <i>et al.</i> (48)	No flossing group
Gjerme and Flötra (49)	Insufficient data presentation
Mohammed and Monserrate (50)	Insufficient data presentation

and age of participants varied per group and study. Information regarding the study characteristics is displayed in Table 3.

Study design and evaluation period

All 11 papers presented a randomized, controlled trial. Four had a cross-over study design (I, VI, X and XI) and seven had a parallel design (II, III, IV, V, VII, VIII and IX). The selected studies varied from 4 weeks to 6 months in duration. When repeated measures were presented, the longest term in the evaluation was used in this review. Hague (I) used a 10 weeks semi-cross-over study design. At baseline, subjects were either assigned to the manual floss group, the automated floss device group or the control group. In the second period, treatment subjects were assigned to the opposite group. The control group continued as such. As this was not a 'true' cross-over that introduces a statistical and methodological problem, it was decided to use only the data from the first leg of the study. These could be entered as being derived from a parallel study design.

Number, age and range of subjects

The number of participants varied per study (range 24–158). The mean age of the participants was approximately 28 years

and varied from 18 to 70 years. In studies VI and IX, the age of the participants was not mentioned.

Two studies (IX, XI) were carried out on dental students. One study (VI) used participants who previously received periodontal treatments and had multiple open interproximal spaces. Another study (VIII) particularly selected participants with generalized gingival inflammation. Some studies had specific requirements, such as an initial gingivitis index of at least 1.0 as determined by using the Löe–Silness Gingival Index (60) and an initial plaque index of at least 1.5 as determined by using the Turesky modification (61) of the Quigley–Hein Plaque Index (62) (III). Study IV used the following inclusion criteria: a PBI (63) per tooth ≥ 0.5 and a Modified Proximal Plaque Index (MMPI) (64, 65) per tooth ≥ 1.5 . Another study (V) required at least one test site that was defined as an interproximal space of 1.0 mm that exhibited bleeding. The participants in study VII required at least 10 interproximal bleeding sites. Two studies used participants with good dental health (I, II).

Intervention and study funding

This systematic review focused on the use of dental floss in addition to manual toothbrushing. One study compared two different kinds of dental floss (X) namely, waxed floss and unwaxed floss. Six studies used waxed floss (I, II, III, IV, VII and XI), and four studies used unwaxed floss (V, VI, VIII and XI). The brands used are shown in Table 3.

William Getgey Company (Cincinnati, OH, USA) supported two papers (I, II). Five other companies support one study each, Colgate-Palmolive Company (III) (New York, NY, USA), GlaxoSmithKline (Bühl, Germany) (IV), Sunstar Inc. (Osaka, Japan) (V), Oral-B Laboratories (Redwood City, CA, USA) (VI), Johnson & Johnson Dental Care Company (VII) (New Brunswick, NJ, USA). Study VIII, IX, X and XI did not report industry funding. Only the authors of study I report no conflicts of interest related to this study.

Prophylaxis and oral hygiene instruction

In four of the studies (III, VI, VIII and IX), participants in the test and control groups received a complete oral prophylaxis. One study (IV) provided the participants with a calculus removal in the lower front teeth and another study (V) removed plaque by polishing. One study (X) consisted of three consecutive experimental periods. On the first day of each experimental period, the teeth were scaled and polished. Four studies did not mention whether the participants received an oral prophylaxis (I, II, VII and XI).

Table 3. Overview of the studies processed for data extraction

No.	References	Title	Design, blinding and evaluation period	No. of subjects, gender, and age	Dental floss used: waxed/unwaxed, frequency, Oral Hygiene Instruction	Toothbrush used, frequency, Oral Hygiene Instruction	Authors' conclusions
I	Hague and Carr (52)	Efficacy of an automated flossing device in different regions of the mouth	RCT, Cross-over, Examiner blind, 10 weeks	70 subjects ♂: 21 ♀: 49 Mean age: Control group 23.3 years Treatment group 23.0 years Range: ?	Glide Floss ComfortPlus, Procter & Gamble Waxed 1 x daily OHI based on ADA recommendations	Oral-B Indicator, soft compact 35 tooth brush, Procter & Gamble, Cincinnati, OH, USA 2 x daily OHI based on ADA recommendations	Using floss in addition to a toothbrush removed significantly more plaque than using a toothbrush only. Floss did not have an additional effect on gingivitis
II	Hague et al. (67)	Evaluation of the safety and efficacy of an automated flossing device: a randomized controlled trial	RCT, Parallel, Examiner blind, 30 days	76 subjects ♂: 22 ♀: 54 Mean age: 23.3 years Range: ?	Glide Floss ComfortPlus, Procter & Gamble Waxed 1 x daily OHI based on ADA recommendations	Oral-B Indicator, soft compact 35 tooth brush, Procter & Gamble, Cincinnati, OH, USA 2 x daily OHI based on ADA recommendations	Floss does not significantly remove more plaque than a toothbrush when it is used in adjunction to a toothbrush nor is there less inflammation
III	Schiff et al. (55)	A clinical investigation of the efficacy of three different treatment regimens for the control of plaque and gingivitis	RCT, Parallel, Examiner blind, 6 months	74 subjects ♂: 46 ♀: 28 Mean age: 27.1 years Range: 18–46	Colgate® Dental Floss, Colgate-Palmolive Company, New York, NY, USA Waxed 1 x daily OHI: no	Colgate® Plus, Colgate-Palmolive Company, New York, NY, USA 2 x daily OHI: no	There was no statistically significant difference in both gingivitis and plaque formation between brushing and brushing and flossing
IV	Zimmer et al. (56)	Clinical efficacy of flossing versus use of antimicrobial rinses	RCT, Parallel, Examiner blind, 8 weeks	78 subjects ♂: 39 ♀: 39 Mean age: 31.7 years Range: 20–64.4	Glide Comfort Plus, Glide, Elkton, MD, USA Waxed 1 x daily OHI: yes	Dr Best flex plus medium, GlaxoSmithKline Frequency: ? OHI: no	There were no differences between the floss group and the brush only group with respect to the plaque and the bleeding index
V	Jared et al. (57)	Clinical trial of a novel interdental brush cleaning system	RCT, Parallel, Examiner blind, 4 weeks	61 subjects ♂: ? ♀: ? Mean age: 36.55 yrs Range: ?	GUM® Easy-through floss (Sunstar Inc., Japan) Unwaxed 1 x daily OHI: yes	GUM® no. 409 (Sunstar Inc., Japan) 2 x daily OHI: yes	Use of floss after 4 weeks significantly reduced plaque in comparison to the use a toothbrush alone. With regard to gingivitis scores, the results did not achieve statistical significance. Statistical analysis of the bleeding scores produced no discernible pattern or useful insight

Table 3. (Continued)

No.	References	Title	Design, blinding and evaluation period	No. of subjects, gender, and age	Dental floss used: waxed/unwaxed, frequency, Oral Hygiene Instruction	Toothbrush used, frequency, Oral Hygiene Instruction	Authors' conclusions
VI	Kiger <i>et al.</i> (53)	A comparison of proximal plaque removal using floss and interdental brushes	RCT, Cross-over, Examiner blind, 3 months	30 subjects ♂: 20 ♀: 10 Mean age: ? Range: ?	Unwaxed dental floss (Johnson & Johnson Products, Inc., New Brunswick, NJ, USA) Frequency: ? OHI: yes	Standard Oral-B 40 toothbrush (Oral-B Laboratories, Inc., Redwood City, CA, USA) Frequency: ? OHI: yes	The toothbrush in combination with floss is significantly more effective in the removal of plaque from the proximal surfaces than a toothbrush alone. This was not true for the gingival index scores
VII	Finkelstein <i>et al.</i> (66)	Mechanical devices versus antimicrobial rinses in plaque and gingivitis reduction	RCT, Parallel, Blinding: ?, 12 weeks	62 subjects ♂: ? ♀: ? Mean age: ? Range: ?	Waxed Dental floss: (Waxed Dental Floss, Johnson & Johnson) Frequency: ? OHI: ?	Product: ? Frequency: ? OHI: ?	Compared to the control group, there was no significant reduction with respect to visual inflammation, number of bleeding sites or the amount of plaque in subjects using dental floss
VIII	Walsh and Heckman (59)	Interproximal subgingival cleaning by dental floss and the toothpick	RCT, Parallel, Examiner blind, 3 months	24 subjects ♂: 15 ♀: 21 Mean age: 36yrs range: 30-70	Product: ? Unwaxed 1 x daily OHI: yes	Product: ? 1 x daily OHI: no	Floss used subgingivally in interproximal surfaces significantly reduced gingival bleeding in comparison with toothbrushing alone. There was no significant difference in plaque removal
IX	Vogel <i>et al.</i> (58)	Evaluation of cleaning devices in the maintenance of interproximal gingival health	RCT, Parallel, Examiner blind, 33 days	24 subjects ♂: ? ♀: ? Mean age: ? Range: ?	Product: ? Unwaxed 1 x daily OHI: yes	Product: ? 1 x daily OHI: yes	There were no significant differences between the brushing group and the brushing and flossing group with respect to gingival inflammation and the amount of plaque
X	Hill <i>et al.</i> (54)	The effects of waxed and unwaxed dental floss on interdental plaque accumulation and interdental gingival health	RCT, Cross-over, Examiner blind No, 98 days	36 subjects ♂: 35 ♀: 1 Mean age: ? Range: 23-37	Product: ? Waxed and unwaxed 1 x daily OHI: yes	Product: ? Frequency: ? OHI: no	There were no significant differences between the floss groups and the toothbrushing group either in plaque accumulation or the condition of the gingiva
XI	Gjeramo and Fløira (51)	The effect of different methods of interdental cleaning	RCT, Cross-over, Examiner blind, 6 weeks	24 subjects ♂: ? ♀: ? Mean age: 23 years Range: ?	Product: ? Waxed Frequency: ? OHI: yes	Product: ? Frequency: ? OHI: ?	The dental floss group had significantly less plaque than the brushing group

RCTs, Randomized Controlled Clinical Trials; OHI, Oral Hygiene Instruction; ?, unknown.

Concerning the oral hygiene instruction given, four studies (IV, VIII, X and XI) only gave verbal, written and/or visual floss instructions. Instructions for both flossing and toothbrushing were given in the remaining seven studies. Studies I and II described that both floss and toothbrush instructions were given according to the ADA recommendations by a dental health educator. One study (III) did not mention whether the participants received oral health instructions concerning their test products.

Indices and parameters of periodontal disease

Plaque

To score plaque, we used the Turesky modification (61) of the Quigley–Hein Index (62) (I, II, III and V), the MMPI (64), Zimmer *et al.* (65) (IV), the Wolffe Index for Proximal Plaque (22) (VI), the Plaque Index of Silness and Loe (68) (VIII, XI), the Podchadley's Index (69) (IX) and the Simplified Oral Hygiene Index of Greene and Vermillion (70) (X).

Gingivitis

Gingival inflammation was assessed according to the Loe and Silness Gingival Index (60) (I, II, III, VI, VII, IX and X) and the Lobene modification of the gingival index (71) (V).

Bleeding on probing

Five studies assessed gingivitis by scoring bleeding upon probing. Each of them used a different index, such as the PBI (63) (IV), the Bleeding on Marginal Probing is the Lie *et al.* (72) modification of the angulated bleeding index (73) (V) and the Eastman Interdental Bleeding Index (74) (VII). Study VIII did not mention which index was used to score bleeding.

Quality assessment

Method of randomization

All of the studies randomly assigned the subjects to the different groups with test products. In the study I, it is mentioned that a computer-generated, randomized sequencing was used and study II assigned their subjects via a rolling enrolment. A block randomization was used in study V. Subjects in study III were stratified into balanced groups according to their baseline supragingival plaque scores, which were then randomly assigned to the treatment regimens. Three other studies (IV, VIII and X) were stratified by gender and papillary bleeding,

age and percentages of sites of bleeding on probing and mean interproximal plaque accumulation and interdental inflammation scores respectively.

Procedures to conceal patient allocations were not described in most of the studies. Studies IV and VI explicitly mentioned that a person not involved in the examination performed the assignment of the subjects to the groups.

Blinding of examiners

The examiners in ten studies were blinded to the patients' intervention assignments during examination (I, II, III, IV, V, VI, VIII, IX, X and XI). In one study, it was not clear whether the examiner was blinded (VII).

Completeness of follow-up

Seven studies (I, IV, VI, VIII, IX, X, XI) reported no loss of subjects to follow-up. Five studies did report follow-up loss. Several reasons were mentioned: scheduling conflicts (II), refusal to use the products assigned (II), not meeting the criteria (VII), withdrawal prior to baseline (V) and non-compliance (III).

Study outcomes

Comparison baseline-end (within groups)

Plaque

Table 4 shows the results from the data extraction. In five studies (IV, V, VIII, X and XI), significant improvements were observed from baseline to end. Three of these studies (IV, V and X) showed this significant improvement for both the toothbrushing followed by flossing and toothbrushing only groups. The other two (VIII, XI) had significant improvement exclusively in the toothbrushing and flossing group.

Two studies did not find significant improvements (VI, IX) and the remaining four (I, II, III and VII) did not mention whether the end score differed significantly from the baseline score.

Gingivitis

Only one study (V) found a significant difference between baseline and end scores for both groups (Table 5). Four studies (I, II, III and VII) did not describe significant differences between baseline and end scores. No significant improvements were found in three studies (VI, IX and X).

Table 4. **Plaque index scores**

No.	Intervention/ groups	Index	Mean (SD)		
			PI baseline	PI end score	Difference:
I	tb + f tb	Turesky modification (61) of the Quigley and Hein Index (62)	2.34 (0.34)	1.29 (0.59) ^{?,‡}	-1.05 ^{?,◇}
			2.37 (0.24)	1.52 (0.62)	-0.85 ^{?,◇}
II	tb + f tb	Turesky modification (61) of the Quigley and Hein Index (62)	2.40 (0.36)	1.44 (0.76) [◇]	-0.96 ^{?,◇}
			2.38 (0.25)	1.59 (0.74) [◇]	-0.79 ^{?,◇}
III	tb + f tb	Turesky modification (61) of the Quigley and Hein Index (62)	2.09 (0.25)	1.51 (0.18)	-0.58 [?]
			2.15 (0.31)	1.53 (0.21)	-0.62 [?]
IV	tb + f tb	MMPI (64)	2.28 (0.31)	1.88 (0.45)	-0.63 ^{◇,•}
			2.20 (0.33)	1.88 (0.50)	-0.32 ^{◇,•}
V	tb + f tb	Turesky modification (61) of the Quigley and Hein Index (62)	2.86 (0.63)	2.23 (0.83)*	-0.63 ^{◇,•}
			2.99 (0.82)	2.97 (0.81)	-0.02 ^{◇,•}
VI	tb + f tb	Wolffe Index for proximal plaque (22)	\bar{X} 1.92 (1.03)	1.71 (0.85)*	-0.21 [◇]
				2.32 (0.69)	0.40 [◇]
VII	tb + f tb	Global Plaque Index	12.2%	5.5%	55% [?]
			12.3%	5.9%	52% [?]
VIII	tb + f tb	Plaque Index of Silness and Loë (68)	93% (0.07)	88% (0.08)	-0.05 [•]
			86% (0.05)	93% (0.09)	0.07
IX	tb + f tb	Podchadley's Index (69)	0.34	0.36	0.02
			0.21	0.30	0.09
X	tb + uw f tb + w f tb	Oral Hygiene Index-Simplified of Greene and Vermillion (70)	\bar{X} = 1.3 (0.80) [◇]	\bar{X} = 1.17 (0.77) [◇]	-0.13 ^{◇,•}
			\bar{X} = 1.3 (0.83) [◇]	\bar{X} = 1.17 (0.87) [◇]	-0.13 ^{◇,•}
			\bar{X} = 1.3 (0.86) [◇]	\bar{X} = 1.36 (0.97) [◇]	0.06 ^{◇,•}
XI	tb + f tb	Plaque Index of Silness and Loë (68)	Only the lingual aspect of the mesial surfaces of the teeth were examined \bar{X} = 0.88	0.53*	-0.35*
			0.86	-0.02	

MMPI, modified proximal plaque index; PI, plaque index.

*Significantly different from brushing only group.

[?]Significance is not mentioned.

[◇]Calculated by the authors.

*Significant difference between baseline and end score.

tb = Toothbrush only.

f = Dental floss.

uw f = Unwaxed floss.

w f = Waxed floss.

Bleeding

Four out of the 11 studies observed the effect on bleeding index scores, two (IV, VIII) observed a significant improvement. One study (IV) presented it for both groups. In contrast, the other (VIII) showed a significant difference in favour of the brush and floss group (Table 6). Studies V and VII did not report whether there was a significant difference.

Between groups

Table 7 shows whether there is a significant difference in the plaque score, gingival score and bleeding score in

favour of dental floss. Of the 11 studies that observed the effect of dental floss on plaque removal, three studies showed a significant effect in favour of dental floss (V, VI and XI). These studies showed an additional effect of floss as an adjunct to toothbrushing. There was significantly less plaque when compared with the use of a toothbrush alone.

When observing visual signs of gingival inflammation, none of the eight studies that studied gingival inflammation found a significant effect of dental floss as adjunct to toothbrushing. Four studies used the bleeding index as a clinical parameter, of which only one found a significant difference in favour of floss (VIII).

Table 5. **Gingival index scores**

No.	Intervention/ groups	Index	Mean (SD)		
			GI baseline	GI end score	Difference: end – base
I	tb + f tb	Löe and Silness Gingival Index (60)	0.83 (0.28)	0.56 (0.28) [?]	-0.34 [?]
			0.90 (0.29)	0.67 (0.35)	-0.16 [?]
II	tb + f tb	Löe and Silness Gingival Index (60)	0.941 (0.195)	0.579 (0.43) [◇]	-0.362 [?]
			0.993 (0.264)	0.666 (0.39) [◇]	-0.327 [?]
III	tb + f tb	Löe and Silness Gingival Index (60)	1.02 (0.05)	1.01 (0.11)	-0.01 [?]
			1.25 (0.40)	1.05 (0.11)	-0.20 [?]
V	tb + f tb	Lobene modification of the gingival index (71)	2.24 (0.66)	1.29 (0.70)	-0.95*
			2.09 (0.67)	1.56 (0.64)	-0.53*
VI	tb + f tb	Löe and Silness Gingival Index (60)	\bar{X} 0.31 (0.19)	0.36 (0.19) 0.37 (0.19)	0.05 0.06
VII	tb + f tb	Löe and Silness Gingival Index (60)	0.18	0.13	-0.05 28% [?]
			0.19	0.15	-0.04 21% [?]
IX	tb + f tb	Löe and Silness Gingival Index (60)	0.24	0.22	-0.02
			0.19	0.27	0.08
X	tb + unwaxed fl tb + waxed fl tb	Löe and Silness Gingival Index (60)	\bar{X} : 0.20 (0.43) [◇]	\bar{X} : 0.37 (0.33) [◇]	-0.17
			\bar{X} : 0.37 (0.63) [◇]	\bar{X} : 0.37 (0.70) [◇]	0.00
			\bar{X} : 0.33 (0.47) [◇]	\bar{X} : 0.37 (0.43) [◇]	0.04

Values are represented as mean (SD).

GI, gingival index.

For abbreviations, see Table 4.

Table 6. **Bleeding index scores**

No.	Intervention/ groups	Index	Mean (SD)		
			BI baseline	BI end score	Difference: end – base
IV	tb + f tb	PBI (1975)	1.19 (0.44)	0.77 (0.52)	-0.42*
			1.27 (0.45)	0.89 (0.46)	-0.38*
V	tb + f tb	Bleeding on marginal probing (72) modification of the angulated bleeding index (73)	100.00%	68.97%	31.03% [?]
			100.00%	81.25%	18.75% [?]
VII	tb + f tb	Eastman Interdental Bleeding Index (1958)	0.62	0.36	-0.26 42% [?]
			0.58	0.41	-0.17 29% [?]
VIII	tb + f tb	?	76% (0.12)	64% (0.14)*	-0.12*
			73% (0.12)	90% (0.10)	0.17

Values are represented as mean (SD).

BI, bleeding index; PBI, papillary bleeding index.

*Significantly different from brushing only group.

For abbreviations, see Table 4.

Meta-analysis

From the collective data of the studies, it appeared to be possible to perform a meta-analysis for plaque index and gingival index scores (Figs 1 and 2). For the Quigley and Hein plaque index (62) (I, II, III and V) and the Löe and Silness gin-

gival index (60) (I, II, III, VI and X), data were presented in more than one study. Data from study X were used twice: once each for each separate set of data for waxed and unwaxed floss.

Figs 1 and 2 provide a summary of the outcomes of the meta-analysis. In both instances, baseline scores were not

Table 7. Overview of the results of the dental floss and toothbrush group in comparison with the toothbrush only group

No. References	Plaque score	Gingival score	Bleeding score	Comparison
I Hague and Carr (52)	?	0	□	Toothbrush
II Hague <i>et al.</i> (67)	0	0	□	Toothbrush
III Schiff <i>et al.</i> (55)	0	0	□	Toothbrush
IV Zimmer <i>et al.</i> (56)	0	□	0	Toothbrush
V Jared <i>et al.</i> (57)	+	0	0	Toothbrush
VI Kiger <i>et al.</i> (53)	+	0	□	Toothbrush
VII Finkelstein <i>et al.</i> (66)	0	0	0	Toothbrush
VIII Walsh and Heckman (59)	0	□	+	Toothbrush
IX Vogel <i>et al.</i> (58)	0	0	□	Toothbrush
X Hill <i>et al.</i> (54)	0	0	□	Toothbrush
XI Gjermeo and Flötra (51)	+	□	□	Toothbrush

+ = significant difference in favour of test group, 0 = no significant difference, □ = no data available, ? = unknown.

statistically different. For the plaque index WMD -0.04, 95% CI (-0.12, 0.04), *P* = 0.39, and for the gingival index WMD -0.08, 95% CI (-0.16, 0.00), *P* = 0.06. End scores also showed no significant difference between both groups for plaque WMD -0.24, 95% CI (-0.53, 0.04), *P* = 0.09 or gingivitis scores WMD -0.04, 95% CI (-0.08, 0.00), *P* = 0.06. The heterogeneity observed at the end-point for the plaque scores (*I*² = 76.4%) should be an indication for the reader not to use the WMD as the exact measure of the effect.

Discussion

Suggestions regarding the benefits of flossing date back to the early 19th century, when the belief was expressed that irritating matter between teeth is the source of dental diseases (23,

75). Over the years, it has been generally accepted that dental floss has a positive effect on removing plaque (8, 10, 11, 76). As dental plaque is naturally pathogenic and dental floss disrupts and removes some interproximal plaque (76), it has been considered that flossing should reduce gingival inflammation. The advocacy of floss as an interdental cleaning device hinges, in large part, on common sense. A common-sense argument is the lowest level of scientific evidence (77). However, dental oral hygiene devices, such as floss, have largely escaped a rigorous scientific evaluation (23). Flossing as the only form of oral hygiene has been shown to be effective in inhibiting the development of gingival inflammation and in reducing the level of plaque (78). In a 21-day non-brushing study, the floss group showed a 31–43% reduction in bleeding scores compared to the group that abstained from any form of oral hygiene. However, the present review aimed to assess systematically the effect of flossing in addition to toothbrushing compared to toothbrushing alone on interproximal plaque and gingivitis. This present systematic review established that dental flossing provides no benefit above and beyond toothbrushing on removing plaque and reducing gingivitis. Based on the individual papers in this review, a trend was observed that indicated a beneficial adjunctive effect of floss on plaque levels; however, this could only be substantiated as a non-significant trend in the meta-analyses.

Methodology of systematic reviews

Several reviews have been published on the efficacy of manual flossing, flossing aids and devices (3, 13–15). In the Brothwell *et al.* review (14), they concluded that there is a high

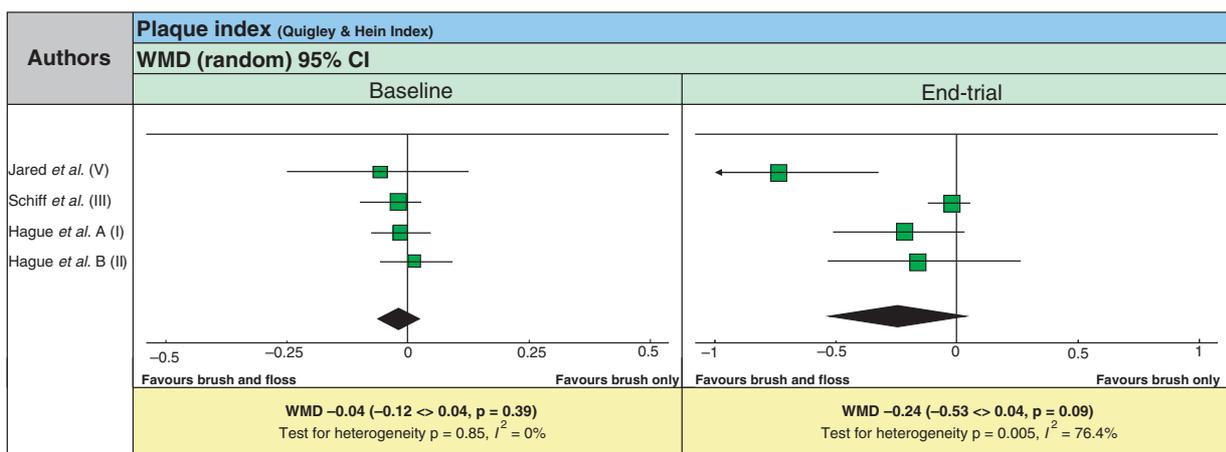


Fig. 1. Plaque data for the studies using dental floss. Forrest-plot demonstrating baseline and values for the Quigley and Hein (62) Plaque Index. The size of the box signifies the 'weight' or importance of the study. Weighted mean differences (WMD = ♦) between floss as an adjunct to toothbrushing and toothbrushing only are provided including the 95% confidence interval (CI).

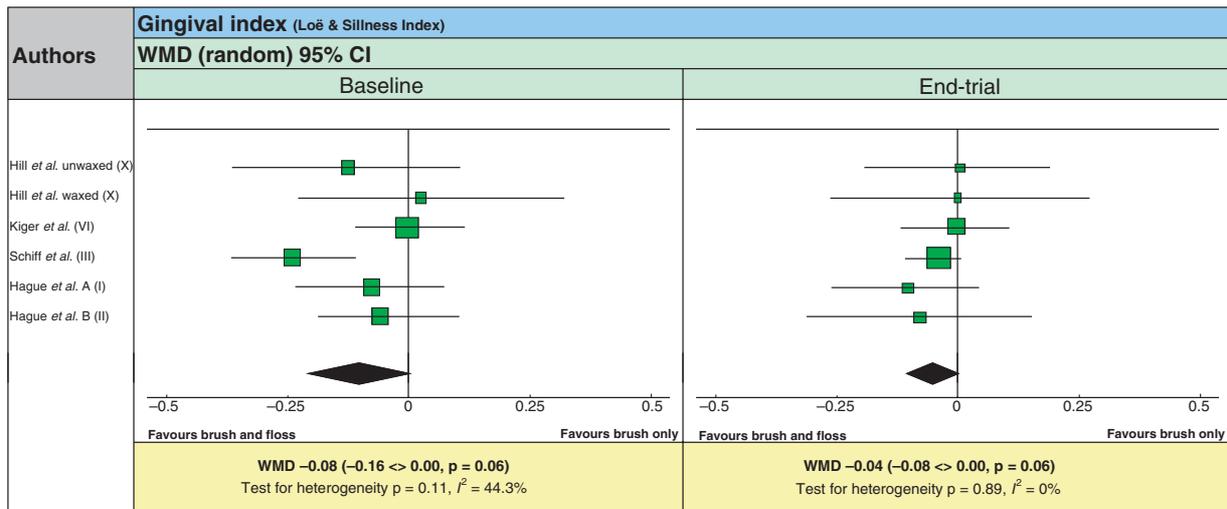


Fig. 2. Gingival data for the studies using dental floss. Forrest-plot demonstrating baseline and values for the Løe and Silness (60) Plaque Index. The size of the box signifies the ‘weight’ or importance of the study. Weighted mean differences (WMD = ♦) between floss as an adjunct to toothbrushing and toothbrushing only are provided including the 95% confidence interval (CI).

level of evidence to support flossing as ‘more effective than toothbrushing alone in controlling gingivitis in adults’. Warren and Chater (13) came to the conclusion that floss is effective, but it depends on the patient’s situation whether it should be recommended. The review of Jahn (15) concluded that floss holders and power flossers demonstrated plaque-removal ability and reduction in gingival inflammation to the same degree as manual flossing. The position paper of the Canadian Dental Hygiene Association (3) concluded that flossing with any type of floss is an effective method of interproximal plaque removal, with the critical note that other methods of interdental cleansing are warranted for some clients and/or for certain oral sites.

In light of all the positivism, one may critically ask why this present systematic review does not substantially show dental floss as a co-operative adjunct to toothbrushing. A possible explanation is that the above-mentioned reviews have not been conducted systematically. They also lack meta-analysis or descriptive analysis based on extracted data. The conclusions are frequently based on studies that compared floss with other interdental cleaners without comparing the effect of floss to a toothbrush alone and often not using a clinical trial model. For this systematic review, a well-formulated, focused question was used. Needleman (79) states that narrowing the scope in a systematic review helps in ensuring that the review will provide a summary as conclusive as the data permit. On the other hand, narrowing the scope of the question also limits the clinical application to only those situations as addressed in the focused question. The present review systematically searched

for papers that investigated the adjunctive effect of flossing to toothbrushing with a manual toothbrush.

Selection within systematic reviews

The Council on Scientific Affairs of the ADA suggests (24) that interdental cleaning devices should be evaluated ‘under unsupervised conditions’ and ‘by the average patient’ for a minimum of 4 weeks. All selected studies lasted at least 4 weeks and the participants had to use floss at home under unsupervised conditions in all selected studies. Two studies (IX, X) selected in the present review were carried out with dental students. As dental students are aware of flossing and brushing technique and the relevance of good oral hygiene, these test groups have an advantage above the test groups in other studies. It is interesting that there was no significant difference between the flossing group and the flossing and toothbrushing group in these studies. It may be concluded that when dental floss does not significantly remove more dental plaque in the ‘professionally educated’ group, it may even be more difficult to find such a result in the ‘general population’.

Effects

The fact that dental floss has no additional effect on toothbrushing is apparent not in this review alone. Hujoel et al. (23) found that flossing was only effective in reducing interproximal caries risk when applied professionally. Their systematic review showed that high-quality professional flossing performed in first-

grade children on school days reduced caries risk by 40%. Self-flossing, on the contrary, failed to have a beneficial effect. The lack of effect on caries, as well as the absence of an effect on gingivitis in the present review, is most likely the consequence of the plaque not being removed as efficiently as can be concluded for the present meta-analysis.

Meta-analysis

The results of this review showed that only three individual studies of a total of 11 studies observed a significant difference in favour of floss as an adjunct to toothbrushing. Based on the use of the same (Quigley and Hein) plaque index, one of these positive-outcome studies with three of the negative/unknown effect studies (Table 7) were suitable for the meta-analysis.

There was no detectable significant difference in the plaque index between the toothbrushing and flossing group and the toothbrushing only group (WMD = -0.24 ; 95% CI: $-0.53, -0.04$, $P = 0.09$) (Fig. 1). Study I with an unknown significant effect (Table 7) showed no significant difference in end scores, which can be concluded based on the confidence interval (95% CI: $-0.51, 0.05$). Figure 2 shows that there was also no effect on gingivitis scores ($P = 0.06$, 95% CI: $-0.08, 0.00$). However, P -values convey little information about study findings and rely on an arbitrary convention of using the 5% level of statistical significance to define two alternative outcomes, significant or not significant. Confidence intervals are more informative than P -values (80). The fact that both plaque and gingivitis values show no significant effects enhances the outcome that floss has no effect above and beyond toothbrushing. However, the 95% CI of the plaque index appears to be skewed because '0.00' lies at the border of the interval. This suggests a trend in favour of brushing and floss. Therefore, the cause of not reaching the level of significance could be a lack of power. However, one should be careful with this interpretation because the baseline data are already skewed towards an effect in favour of brushing and floss. The 95% CI of the end gingivitis index scores was small and narrow and lies snugly to '0.00', which leaves no doubt about the absence of the effect of floss on gingival inflammation. With respect to gingival inflammation, the end WMD was -0.04 ($P = 0.06$). Heterogeneity was not significant. Therefore, the exact measure of the WMD can be taken as the effect and this was very small and not significant.

Patient's compliance

Research also shows that few individuals floss correctly (81). An inability to floss correctly may cause a lack of motivation

(82). It is important to recognize that when one is assessing the effectiveness of interdental cleaning methods, two points of reference should be considered. The first and most obvious is the theoretical efficacy of the method based on clinical evidence. A second point of reference is the practical efficacy influenced by the acceptability of the method to patients and, therefore, their compliance (3, 13, 83). Historically, compliance with regular flossing has been far less than ideal. The routine use of dental floss has consistently been shown to be dramatically low. Research has shown a range of daily use among adults ranging from 10% to as high as 30% (3). The reasons for this lack of compliance apparently encompass two issues: (1) a lack of patient ability and (2) a lack of motivation. Studies are inconsistent in their ability to demonstrate that educational attempts to influence floss frequency can be successful (3). However, it has also been shown that flossing is like any other skill in that it can be taught and those who are given appropriate instruction will increase their flossing frequency (3, 84, 85). Sniehotta *et al.* (86) provided evidence for the effects of a concise intervention on oral self-care behaviour. Other studies have shown that educational attempts to modify client behaviour were not successful in improving floss frequency (3, 87).

Evidence-based advice

Dental hygienists are often the primary source for professional information on oral disease prevention for those members of the public who are able to access oral care (3, 15, 88). They are viewed as having both the appropriate knowledge base and an acute understanding of the individual needs of their clients. To address plaque-mediated oral disease, dental professionals have traditionally recommended daily mechanical plaque removal and, more specifically, toothbrushing in conjunction with flossing (3, 8, 26). In the context of evidenced-based dentistry, every dental professional must make a well-considered decision as to what to advise to the patient. For this decision, clinical expertise, patient values, available necessities and research evidence are necessary (89). A systematic review has a high level of evidence and it is a systematic assessment of the available literature on the effects of healthcare interventions that intended to help the professional in this process (90). In light of the results of this comprehensive literature search and critical analysis, it is concluded that routine instruction of flossing in gingivitis patients as helpful adjunct therapy is not supported by scientific evidence. The dental professional should determine, on an individual patient basis, whether high-quality flossing is an achievable goal.

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