Multi-Disciplinary Management of Periodontal Disease
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Chapter 3

Interdental oral hygiene: The evidence

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Introduction

There is increasing public awareness of the value of personal oral hygiene. People brush their teeth for a number of reasons: to feel fresh and confident, to have a nice smile, and to avoid bad breath and disease. Oral cleanliness is important for the preservation of oral health as it removes microbial plaque, preventing it from accumulating on teeth and gingivae (Choo *et al* 2001). Maintenance of effective plaque control is the cornerstone of any attempt to prevent and control periodontal disease. The benefits of optimal home-use plaque-control measures include the opportunity to maintain a functional dentition throughout life. Self-care has been defined by the World Health Organization as all the activities that the individual takes to prevent, diagnose and treat personal ill health by self-support activities or by referral to a healthcare professional for diagnosis and care (Claydon 2008).

There is substantial evidence showing that toothbrushing and other mechanical cleansing procedures can reliably control plaque, provided that cleaning is sufficiently thorough and performed at appropriate intervals. Evidence from large cohort studies has demonstrated that high standards of oral hygiene will ensure the stability of periodontal tissue support (Axelsson 2004, Hujoel *et al* 2006).

Interdental plaque control is essential to every patient's self-care program. Several dental conditions result from infrequent or ineffective interdental cleaning, including caries and periodontal diseases. These two, in combination, suggest a need for effective interdental cleaning. It is therefore important that the effectiveness of these interdental oral hygiene products be assessed and understood. The present review was undertaken to provide the dental professional with the available scientific evidence.

Interdental devices

There is confusion in the literature with respect to the definitions of *approximal, interproximal, interdental,* and *proximal* sites. Commonly used indices are not suitable for assessing interdental plaque (directly under the contact area), and thereby limit interpretation of interdental plaque removal. The European Workshop on Mechanical Plaque Control in 1999 proposed the following definitions: *approximal* (proximal) areas are the visible spaces between teeth that are not under the contact area. In health these areas are small, although they may increase after periodontal attachment loss. The terms

interproximal and *interdental* may be used interchangeably and refer to the area under and related to the contact point.

The interdental gingiva fills the embrasure between two teeth apical to their contact point. This is a 'sheltered' area that is difficult to access when teeth are in their normal positions. In populations that use toothbrushes, the interproximal surfaces of the molars and premolars are the predominant sites of residual plaque. The removal of plaque from these surfaces remains a valid objective because in patients susceptible to periodontal disease, gingivitis and periodontitis are usually more pronounced in this interdental area than on oral or facial aspects (Löe 1979). Dental caries also occurs more frequently in the interdental region than on lingual and buccal smooth surfaces. A fundamental principle of prevention is that the effect is greatest where the risk of disease is greatest. Toothbrushing alone does not reach the interproximal areas of teeth, resulting in areas of teeth that remain unclean. Good interdental oral hygiene requires a device that can penetrate between adjacent teeth.

Many different commercial products are designed to achieve this goal, including floss, woodsticks, rubber-tip simulators, interdental brushes, single-tufted brushes, and recently introduced electrically powered cleaning aids (i.e. oral irrigators). Flossing is the most advocated method since it can be performed in nearly all clinical situations. While picking teeth may be one of humanity's oldest habits, not all interdental cleaning devices suit all patients or all types of dentition (Galgut 1991). Factors such as the contour and consistency of gingival tissues, the size and form of the interproximal embrasure, tooth position, and alignment and patient ability and motivation should be taken into consideration when recommending an interdental cleaning method.

Dental floss

Reports of the benefits of flossing date back to the early 19th century, when it was believed that irritating matter between teeth was the source of dental disease (Hujoel *et al* 2006, Parmly 1819). Over the years, it has been generally accepted that dental floss has a positive effect on removing plaque (Axelsson 2004, Darby & Walsh 2003, Waerhaug 1981, Wilkins 2004). Even subgingival plaque can be removed, since dental floss can be introduced 2 to 3.5 mm below the tip of the papilla (Waerhaug 1981) (Figure 1). The ADA reports that up to 80% of plaque may be removed by this method (ADA 1984). As dental plaque is naturally pathogenic and dental floss disrupts and removes some interproximal plaque, it has been thought that flossing should reduce gingival inflammation (Waerhaug 1981). Flossing as the sole form of oral hygiene has been shown to be effective in preventing the development of gingival inflammation and reducing the level of plaque (Barendregt *et al* 2002).

Figure 1. Floss can be introduced 2 to 3.5 mm subgingivally relative to the tip of the interdental papilla.

Berchier and co-workers (2008) conducted a systematic review of scientific literature to investigate the efficacy of dental floss as an adjunct to toothbrushing on plaque and parameters of gingival inflammation, in adults with periodontal disease. Eligible studies provided a test group that used dental floss as an adjunct to toothbrushing and a control group that used toothbrushing only. The MEDLINE and CENTRAL databases were searched through December 2007 to identify appropriate studies. Plaque and gingivitis were selected as outcome variables. Independent screening of titles and abstracts resulted in 11 publications that met the eligibility criteria.

The majority of these studies showed that there was no benefit from floss on plaque or clinical parameters of gingivitis (Table 1). From the collective data of the studies, it appeared possible to perform a meta-analysis of plaque and gingival index scores. Table 2 provides a summary of the outcomes of the meta-analysis. In both instances, baseline scores were not statistically different. Comparing brushing and flossing against brushing only, the plaque index WMD was -0.04 (95% CI: -0.12; 0.04, P = 0.39) and the gingival index WMD was -0.08 (95% CI: -0.16; 0.00, P = 0.06). End scores also showed no significant differences between groups for plaque (WMD: -0.24, 95% CI: -0.53; 0.04, P = 0.09) or gingivitis (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%) indicates that the WMD should not be used as the exact measure of results. Based on the individual papers in this review, a trend that indicated a beneficial adjunctive effect of floss on plaque levels was observed. However, this could only be substantiated as a non-significant trend in the meta-analyses. The dental professional should therefore determine, on an individual patient basis, whether high-quality flossing is an achievable goal. If this is likely to be the case, daily flossing may be introduced as the oral hygiene

Author(s)	**Plaque score**	**Gingival score**	**Bleeding score**
Finkelstein *et al* (1990)	0	0	0
Gjermo *et al* (1970)	+	^	^
Hague and Carr (2007a)	?	0	^
Hague *et al* (2007b)	0	0	^
Hill *et al* (1973)	0	0	^
Jared *et al* (2005)	+	0	0
Kiger *et al* (1991)	+	0	^
Schiff *et al* (2006)	0	0	^
Vogel *et al* (1975)	0	0	^
Walsh *et al* (1985)	0	^	+
Zimmer *et al* (2006)	0	^	0

Table 1. Descriptive overview of the results of the dental floss and toothbrush group compared to the toothbrush only group.
+ = significant difference in favor of toothbrush & floss group, 0 = no significant difference, ^ = no data available, ? = unknown. (Berchier *et al* 2008)

Studies included	Index		WMD (random)	95% CI	Overall effect	Test for heterogenicity	
Jared *et al* (2005)	Plaque index;	Base	-0.04	-0.12; 0.04	P=0.39	P=0.85	I^2=0%
Hague & Carr (2007a)	Quigley & Hein	End	-0.24	-0.53; 0.04	P=0.09	P=0.005	I^2=76.4%
Hague *et al* (2007b)	(1962)						
Schiff *et al* (2006)							
Hague & Carr (2007a)	Gingival index;	Base	-0.08	-0.16; 0.00	P=0.06	P=0.11	I^2=44.3%
Hague *et al* (2007b)	Löe & Silness	End	-0.04	-0.08; 0.00	P=0.06	P=0.89	I^2=0%
Hill *et al* (1973) waxed	(1963)						
Hill *et al* (1973) unwaxed							
Kiger *et al* (1991)							
Schiff *et al* (2006)							

Table 2. Meta-analyses between floss as an adjunct to toothbrushing and toothbrushing only. Negative value favors floss. (Berchier *et al* 2008)

tool for interdental cleaning. Routine recommendation to use floss is not supported by scientific evidence as established by Berchier *et al* (2008) in their comprehensive literature search and critical analysis.

One may critically ask why the review by Berchier *et al* (2008) does not substantially show dental floss as a co-operative adjunct to toothbrushing. The advocacy of floss as an interdental cleaning device hinges, in large part, on common sense. However, common sense arguments are the lowest level of scientific evidence (Sackett *et al* 2000). A possible explanation is that the previous narrative reviews have not been conducted systematically. These reviews also lack meta-analysis or descriptive analysis based on extracted data.

The fact that dental floss has no additional effect on toothbrushing is apparent from more than one review. Hujoel *et al* (2006) found that flossing was only effective in reducing the risk of interproximal caries when applied professionally. High-quality professional flossing performed in first-grade children on school days reduced the risk of caries by 40%. In contrast, self-performed flossing failed to show a beneficial effect. The lack of an effect on caries and the absence of an effect on gingivitis in the review by Berchier and coworkers (2008) are most likely the consequence of plaque not being removed efficiently, as established in the present meta-analysis. Flossing does also not effectively clean wide interdental spaces, root surfaces or concavities. Such periodontally involved dentitions are more common with advancing age when reduced dexterity and visual acuity further impede flossing.

Woodsticks

Toothpicks are one of the earliest and most persistent "tools" used to "pick teeth." The toothpick may date back to the days of the cave people, who probably used sticks to pick food from between their teeth. Originally, dental woodsticks were advocated by dental professionals as 'gum massagers' used to massage inflamed gingival tissue in the interdental areas to reduce inflammation and encourage keratinization of the gingival tissue (Galgut 1991).

Woodsticks are designed to allow the mechanical removal of plaque from interdental surfaces. The friction of the sides rubbing against the interproximal tooth surfaces removes the bacterial biofilm. They

Figure 2. Woodsticks are inserted interdentally with the base of the triangle resting on the gingival side. The woodstick is rubbed against the interproximal tooth surfaces.

are fabricated from soft wood to improve adaptation into the interdental space and to prevent injury to the gingiva. They should not be confused with toothpicks, which are meant simply for removing food debris after a meal (Warren & Chater 1996). The round toothpick is too thick and too blunt to reach the lingual half of the tooth when trying to angle it, while the curved surface of the toothpick provides only point contact with the tooth surface. The rectangular woodstick is also designed inappropriately for interdental cleaning as the device is too pliable to be able to clean lingually (Bergenholtz *et al* 1974). However, a triangular woodstick seems to have the correct shape to fit the interdental space (Waerhaug 1959). Woodsticks are inserted interdentally with the base of the triangle resting on the gingival side. The tip should point occlusally or incisally and the triangles against the adjacent tooth surfaces. The tapered form makes it possible for the patient to angle the woodstick interdentally and even clean the lingually localized interdental surfaces. Unlike floss they can be used on the concave surfaces of the tooth root.

The tapered form of a triangular woodstick makes it possible for the patient to angle the device interdentally and even clean the lingually localised interdental surfaces (Morch & Waerhaug 1956). From the results of Bergenholtz *et al* (1974), it may be concluded that triangular woodsticks with low surface hardness and high strength values are preferred for interdental cleaning. From studies performed *in vivo* and from autopsy material, it was shown that a triangular pointed woodstick inserted interdentally can maintain a subgingival plaque-free region of 2 to 3 mm (Morch & Waerhaug 1956). The resilience of the gingival papilla allows cleaning apical to the subgingival margins of fillings (risk surfaces for recurrent caries). For open interdental spaces, common among adults, woodsticks seem most appropriate (Lang & Karring 1994). In periodontitis patients, the woodstick will depress the papilla, which may help in recontouring the interdental tissues and consequently preclude the need for periodontal surgery (Baer & Morris 1977). Woodsticks can only be used effectively where sufficient interdental space is available. Woodsticks have the advantage of being easy to use and can be used throughout the day without the need of a bathroom or mirror (Galgut 1991).

How effective is the woodstick in maintaining oral health? Does it offer any particular advantage over flossing or interdental brushes? Hoenderdos and coworkers (2008) performed a systematic review to evaluate and summarize the available evidence on the effectiveness of using triangular woodsticks in combination with toothbrushing to reduce both plaque and clinical inflammatory symptoms of gingival inflammation. The MEDLINE and CENTRAL databases were searched through February 2008 to identify appropriate studies. Studies were screened independently by two

reviewers. Randomised controlled trials and controlled clinical trials were selected if they were conducted in individuals of over 18 years of age who were in good general health, and which used plaque, bleeding or gingivitis as outcome measures. Case reports, letters, and narrative or historical reviews were excluded and only English-language papers were considered. Independent screening of the titles and abstracts yielded seven publications with eight clinical experiments that met the eligibility criteria.

The heterogeneity of the data prevented quantitative analysis. A qualitative summary is presented in Table 3 which summarizes the differences between woodsticks and other devices. In seven studies, the improvement in gingival health represented a significant incremental benefit realized by the use of triangular woodsticks. Seven publications describing eight clinical experiments met the inclusion criteria. The improvement in gingival health observed in the studies represented a significant reduction of bleeding realised by the use of triangular woodsticks. None of the studies that scored plaque demonstrated any significant advantage of the use of woodsticks over alternative methods of plaque removal in people who had gingivitis.

A series of histological investigations in patients with periodontitis has shown that the papillary area with the greatest inflammation corresponds to the middle of the interdental tissue. It is difficult to clinically assess the mid-interdental area, as it is usually not available for direct visualization (Walsh & Heckman 1985). When used on healthy dentition, woodsticks depress the gingivae by up to 2 mm and therefore clean part of the subgingival area. Thus, woodsticks may specifically remove subgingivally located interdental plaque that is not visible and therefore not evaluated by the plaque index. This physical action of woodsticks in the interdental area may produce a clear beneficial effect on interdental gingival inflammation (Finkelstein

Author(s)	**Plaque score**	**Bleeding score**	**Gingival score**	**Comparison**
Barton (1987)	^	+	^	Toothbrush only
Bassiouny & Grant (1981)	0	^	^	Toothbrush only
Caton *et al* (1993)	^	+	^	Toothbrush only
Finkelstein & Grossman (1984)	0	+	0	Toothbrush only
Gjermo & Flötra (1970) Part 1	0	^	^	Toothbrush only
Bergenholtz & Brithon (1980)	-	^	^	Dental Floss
Finkelstein & Grossman (1984)	0	?	0	Dental Floss
Gjermo & Flötra (1970) Part 1	0	^	^	Dental Floss
Gjermo & Flötra (1970) Part 3	0	^	^	Dental Floss
Wolffe (1976)	0	^	^	Dental Floss
Bassiouny & Grant (1981)	?	^	^	Interdental Brush
Gjermo & Flötra (1970) Part 3	-	^	^	Interdental Brush

Table 3. Descriptive overview of the results for woodsticks compared to other interventions.
+ = significant difference in favor of test group, - = significant difference in favour of the comparison, 0 = no significant difference, ^ = no data available, ? = unknown. (Hoenderdos *et al* 2008)

1990).

Interdental brushes

Interdental brushes were introduced in the 1960s as an alternative to woodsticks. The interdental brush consists of soft nylon filaments twisted into a fine stainless steel wire. This 'metal' wire can prove uncomfortable for patients with sensitive root surfaces. For such patients the use of plastic-coated metal wires may be recommended. The support wire is continuous or inserted into a metal/plastic handle. Interdental brushes are manufactured in different sizes and forms. The most common forms are cylindrical or conical/tapered (like a Christmas tree). The length of the bristles in cross section should be tailored to the interdental space. Appropriate interdental brushes are currently available for the smallest to the largest interdental space which ranges from 1.9 to 14 mm in diameter. Interdental brushes have the added advantage of serving as vehicles for the local application of antibacterial agents or desensitizing agents to exposed sensitive root areas.

Interdental brushes are frequently recommended by dental professionals to patients with sufficient space between their teeth. Interdental brushes are small, specially designed brushes for cleaning between the teeth. They have soft nylon filaments twisted into a fine stainless steel wire. They can be conical or cylindrical in shape and are available in different widths to match the interdental space. Upon examination of extracted teeth from individuals who habitually used interdental brushes, Waerhaug (1976) showed that the supragingival proximal surfaces (the central part of the interdental space and the embrasures) were free of plaque, and that some subgingival deposits were removed up to a depth of 2 to 2.5 mm below the gingival margin.

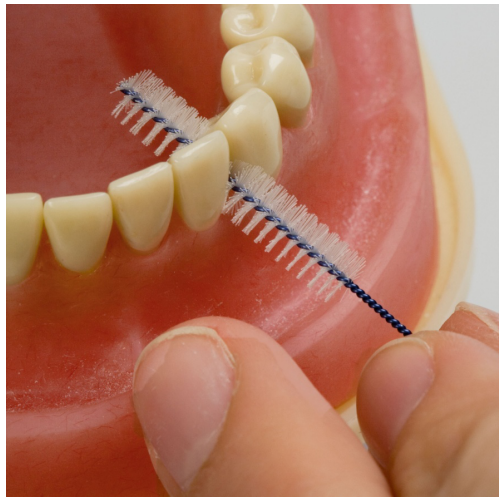

Figure 3. Interdental brushes are inserted interdentally and have an effect of the supragingival proximal surfaces and depths of 2 to 2.5 mm below the gingival margin.

Slot and coworkers (2008) systematically reviewed the literature to determine the effectiveness of interdental brushes used as adjuncts to toothbrushes in terms of plaque and clinical parameters of periodontal inflammation in patients with gingivitis or periodontitis. This situation was compared to toothbrushing alone or toothbrushing in combination with floss or woodsticks. The MEDLINE–PubMed and CENTRAL databases were searched through November 2007 to identify appropriate studies. Two independent reviewers assessed studies for inclusion, aiming to identify appropriate randomised controlled clinical trials and controlled clinical trials. Studies were selected if they were conducted in humans, and included subjects of over 18 years of age in good general health with sufficient interdental space to use an interdental brushes. The articles were limited to English-language publications. Case reports, letters and narrative or historical reviews were excluded. Clinical parameters of periodontal inflammation such as plaque, gingivitis, bleeding, and pockets

Author(s)	Plaque score	Gingival score	Bleeding score	Pocket depth	Comparison
Bassiouny & Grant (1981)	?	^	^	^	Toothbrush only
Jared *et al* (2005)	+	+	0	^	Toothbrush only
Kiger *et al* (1991)	+	0	^	^	Toothbrush only
Christou *et al* (1998)	+	^	0	+	Dental Floss
Gjermo & Flötra (1970)	+	^	^	^	Dental Floss
Ishak & Watts (2007)	0	^	0	0	Dental Floss
Jackson *et al* (2006)	+	^	0	+	Dental Floss
Jared *et al* (2005)	0	0	0	^	Dental Floss
Kiger *et al* (1991)	+	0	^	^	Dental Floss
Rösing *et al* (2006)	+	^	^	^	Dental Floss
Yost *et al* (2006)	0	0	0	^	Dental Floss
Bassiouny & Grant (1981)	?	^	^	^	Woodstick
Gjermo & Flötra (1970)	+	^	^	^	Woodstick

Table 4. Descriptive overview of the results for interdental brushes and other interventions.
+ = significant difference in favor of test group, 0 = no significant difference, ^ = no data available, ? = unknown. (Slot *et al* 2008)

were selected as outcome variables. Independent screening of the titles and abstracts resulted in nine publications that met the eligibility criteria.

Table 4 summarizes differences between interdental brushes and various intervention strategies. All three studies that compared interdental brushes as an adjunct to brushing showed a significant difference in favor of the use of interdental brushes for plaque removal. The majority of the studies showed a positive significant difference on the plaque index when using interdental brushes relative to floss. No differences were found for the gingival or bleeding indices. Two out of three studies showed that interdental brushes, when compared to floss, had a significant positive effect on pocket reduction in patients with periodontitis. Interdental brushes remove more dental plaque than woodsticks, as shown by one of the two comparative studies.

From the collective data of the studies, a meta-analysis appeared to be possible for the comparison of interdental brushes or floss as adjuncts to toothbrushing. Table 5 provides a summary of the outcome of the meta-analysis. In all instances, baseline scores were not statistically different. End scores only showed a significant effect with the Silness and Löe plaque index in favor of the interdental brush group relative to the floss group (WMD: -0.48, 95% CI: -0.65; -0.32, p <0.00001). Comparisons using the other indices (Quigley and Hein plaque index, bleeding on probing and pocket depth) were not statistically significant. The heterogeneity observed with the Silness and Löe index (P = 0.001, I^2 = 85.4%) reflects the different behaviors of the study populations to the study product, differences in study designs and other factors that may influence outcome. Again, the reader should therefore exercise caution when using this WMD as an exact measure of outcomes. Within the limitations of the search and selection strategy of the review, Slot and coworkers (2008) showed that Interdental brushes are a useful device to complement toothbrushing. The evidence suggests that

Studies included	Index		WMD (random)	95% CI	Overall effect	Test for heterogenicity	
Jackson *et al* (2006)	Plaque index;	Base	-0.01	-0.08; 0.06	P=0.84	P=0.97	I^2=0%
Rösing *et al* (2006)	Silness & Löe (1964)	End	-0.48	-0.65; -0.32	P<0.00001	P=0.001	I^2=85.4%
Christou *et al* (1998)	Plaque index;	Base	-0.01	-0.28; 0.26	P=0.94	P=1.0	I^2=0%
Jared *et al* (2005)	Quigley & Hein (1962)	End	-0.25	-0.57; 0.06	P=0.12	P=0.74	I^2=0%
Christou *et al* (1998)	Bleeding on	Base	0.01	-0.04; 0.06	P=0.62	P=0.86	I^2=0%
Ishak & Watts (2007)	probing	End	-0.04	-0.10; 0.02	P=0.17	P=0.74	I^2=0%
Jackson *et al* (2006)							
Christou *et al* (1998)	Pocket	Base	0.14	-0.19; 0.47	P=0.39	P=0.28	I^2=22.0%
Ishak & Watts (2007)	depth	End	-0.04	-0.28; 0.21	P=0.77	P=0.77	I^2=0%
Jackson et al (2006)							

Table 5. Meta-analyses between interdental brushes and floss. Negative value favors interdental brushes. (Slot *et al* 2008)

interdental brushing is the most effective method to remove plaque.

Two out of the three studies that assessed probing pocket depth showed that reduction was more pronounced with interdental brushes than with floss (Christou *et al* 1998, Jackson *et al* 2006). Only Ishak & Watts (2007) could not support this finding. A possible reason that the meta-analysis does not support this advantage is the large difference between the interdental brush and floss groups in these studies at baseline. To overcome this imbalance, an elegant approach would be to use the difference between baseline and end scores as a measure of effect. Only one study provides this information (Christou *et al* 1998). Jackson *et al* (2006) proposed that the reduced pocket depth may have been related to the reduction in swelling with concomitant recession. However, with a lack of effect on signs of gingival inflammation (Table 5), the reason for the effect on pocket depth cannot readily be explained by a reduction in the level of gingival inflammation. As an explanation for the observed effect, the proposition by Badersten *et al* (1984) seems conceivable. They suggested that a mechanical depression of the interdental papilla is induced by interdental brushes, which in turn causes recession of the marginal gingival. This, together with good plaque removal, could be the origin of the improved reduction in pocket depth.

Oral irrigators

Additional oral hygiene aids have been developed in an attempt to augment the effect of toothbrushing on reducing interdental plaque (Warren & Chater 1996). The oral irrigator was introduced in 1962. This device has been demonstrated to be safe and likely provides a particular benefit for gingival health to a large portion of the general public that does not clean interproximal spaces on a regular basis (Cobb *et al* 1988, Lobene 1969, Frascella 2000). Oral irrigation has been a source of controversy within the field of

periodontology. The adjunctive aid of the oral irrigator 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 (Lang & Räber 1981). Patients report that the oral irrigator 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 (Burch *et al* 1994).

Since its introduction, the oral irrigator has at times been a popular device (Newman *et al* 1994). However, there has been considerable controversy regarding the appropriate use and efficacy of this instrument (Astwood 1975, Newman *et al* 1994). Studies using an oral irrigator have reported both positive and negative results in terms of periodontal inflammation and plaque (Aziz-Gandour & Newman 1986, Fine & Baumhammers 1970, Hugoson 1978, Lobene *et al* 1972, Toto *et al* 1969, Walsh *et al* 1989). This inconsistency causes confusion about the efficacy of the oral irrigator.

Husseini and coworkers (2008) performed a systematic review to evaluate the effectiveness of oral water irrigation as an adjunct to toothbrushing on plaque and clinical parameters of periodontal inflammation relative to toothbrushing alone or regular oral hygiene. Papers in the MEDLINE-PubMed and CENTRAL databases up to January 2008 were searched to identify appropriate studies. Papers were assessed for inclusion independently by two reviewers and only those published in the English language were chosen. Randomized controlled clinical trials or controlled clinical trials conducted in adults with good general health were selected. Clinical parameters of periodontal inflammation such as plaque, bleeding, gingivitis and pocket depth were selected as outcome variables. Independent screening of the titles and abstracts of 809 PubMed and 105 Cochrane papers resulted in seven publications that met the eligibility criteria.

Figure 4. Tip of the oral irrigator

The heterogeneity of the data prevented quantitative analysis. Table 6 shows a descriptive analysis of the selected studies. None of the selected studies showed a significant difference between toothbrushing and use of an oral irrigator and only toothbrushing. When the oral irrigator was compared to regular oral hygiene, there were some significant differences for the clinical parameters of periodontitis. With respect to plaque, no significant differences were observed. All three studies that presented data on bleeding scores showed significant reductions in the oral irrigator group compared to the regular oral hygiene group (Flemmig *et al* 1990, Flemmig *et al* 1995, Newman *et al* 1994). When observing visual signs of gingival inflammation, three out of four studies found a significant effect with use of an oral irrigator as an adjunct to regular oral hygiene (Flemmig *et al* 1990, Flemmig *et al* 1995, Newman *et al* 1994). Two of the four studies showed a significant reduction in probing depth as a result of using an oral

Author(s)	Plaque score	Gingival score	Bleeding score	Pocket depth	Comparison
Frascella *et al* (2000)	0	0	0	^	Toothbrush only
Hoover *et al* (1968)	?	^	?	^	Toothbrush only
Walsh *et al* (1989)	0	0	0	?	Toothbrush only
Flemmig *et al* (1995)	0	+	+	+	Regular oral hygiene
Flemmig *et al* (1990)	0	+	+	0	Regular oral hygiene
Meklas *et al* (1972)	0	^	0	^	Regular oral hygiene
Newman *et al* (1994)	0	+	+	+	Regular oral hygiene

Table 6. Descriptive overview of the results of the toothbrush and oral irrigation group relative to the toothbrush only or regular oral hygiene only group.
+ = significant difference in favor of test group, 0 = no significant difference, ^ = no data available, ? = unknown. (Husseini *et al* 2008)

irrigator as an adjunct to regular oral hygiene (Flemmig *et al* 1995, Newman *et al* 1994).

Plaque reduction is a prerequisite for an oral hygiene device to be considered valuable (Newman *et al* 1994). The selected papers for this review reported no statistically significant reduction in plaque with use of an oral irrigator. Despite a lack of effect on the plaque index, studies did find a significant effect on the bleeding index. The mechanisms 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 population of key pathogens (and their associated pathogenic effects) may be altered, reducing gingival inflammation (Flemmig *et al* 1995). 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 (Chaves *et al* 1994). Another possibility is that the beneficial activity of the oral irrigator is at least partly due to removal of food deposits and other debris, flushing away of loosely adherent plaque, removal of bacterial cells, interfering with plaque maturation and stimulating immune responses (Frascella *et al* 2000). Other explanations include mechanical stimulation of the gingiva or a combination of previously reported factors (Flemmig *et al* 1990, Frascella *et al* 2000). Irrigation may reduce plaque thickness, which may not be easily detected using 2-dimensional scoring systems (Jolkovsky *et al* 1990). This may be the reason for an absence of an effect on plaque but a positive effect on gingival inflammation (Table 6).

Husseini and coworkers (2008) concluded that the effectiveness of an oral irrigator as an adjunct to toothbrushing does not have a beneficial effect on reducing plaque scores. However, there is evidence that suggests a positive tendency toward improved gingival health when using an oral irrigator as an adjunct to toothbrushing as opposed to regular oral hygiene (that is self-performed oral hygiene without any specific instruction).

Discussion

Clinicians have choices and make decisions everyday as they provide care for patients. Some of the options may be evidence based, some not. This paper summarizes the highest level of evidence that is currently

available. The systematic reviews included here attempt to collate all empirical evidence that fits pre-specified eligibility criteria to answer a specific research question. They use explicit, systematic methods that are selected to minimize bias, providing more reliable findings from which conclusions can be drawn and decisions can be made (Antman *et al* 1992, Oxman & Guyatt 1993). Systematic reviews of randomized controlled trials are seen as the gold standard for assessing the effectiveness of healthcare interventions. The method of collecting information from a systematic review provides a solid base for clinical decision-making (Newman *et al* 2003). The Cochrane Collaboration declares in the Cochrane Handbook for Systematic Reviews that reviews are needed to help ensure that healthcare decisions throughout the world can be based on informed, high-quality, timely research evidence (Higgens & Green 2006). Using meta-analyses, systematic reviews can provide a quantitative distillation of apparently conflicting clinical data or identify a trend that might not be evident in a narrative review. As valuable as systematic reviews can be, their usefulness depends on the focus and quality of the previously published studies. It is important to interpret results of all research in the context it was performed. In the case of a systematic review, a lack of high quality, homogeneous evidence can result in lack of conclusive findings. In the presented reviews, the high levels of heterogeneity between study designs poses problems in reaching clear clinical recommendations.

According to the American Dental Association, evidenced-based dentistry is an approach to oral health care that requires judicious integration of systematic assessments of clinically relevant scientific evidence, relating the patient's oral and medical condition and history with the dentist's clinical expertise and the patient's treatment needs and preferences (ADA 2009). Best care for each patient rests neither in clinician judgment nor scientific evidence but rather in the art of combining the two through interaction with the patient to find the best option for each individual. Consider the results established following the systematic review on floss. The conclusions have disappointed many dental professionals and believers in the use of floss. The fact that floss does not appear to be effective in the hands of the general public does not preclude its use. For instance, in interdental situations that only allow the penetration of a string of dental floss, this would be the most suitable tool. Although floss should not be the first tool recommended for cleaning open interdental spaces, if the patient does not like any other tool, flossing could still be part of oral hygiene instruction. The dental professional should, however, realize that proper instruction, sufficient motivation of the patient and a high level of dexterity are necessary to make the flossing effort worthwhile.

While most patients brush at least for a short period of time, fewer use interdental devices. Adjunctive aids, including interdental brushes, floss, and mechanical devices, are available to remove interdental plaque. Dental hygienists and their clients are faced with myriad products designed for interproximal tooth cleansing (Asadoorian 2006). The range is overwhelming, from simple dental floss or tape, through woodsticks and brushes (single or multi-tufted). However, what is apparent is that the choice of interdental cleaning method should be tailored to the size and shape of each interdental and proximal space. Furthermore, in order to gain maximum effectiveness, the level of oral hygiene advice delivered to the patient must contain enough information to enable the patient to be able to identify each site in turn, select a device and

effectively clean the whole interdental surface (Claydon 2008). Ongoing patient education is also an integral part of patient compliance. The patient's ability to remove plaque from all areas, including interproximal areas, is an essential part of every patient's selfcare program.

Research shows that few individuals floss correctly (Lang *et al* 1995). The inability to floss correctly may cause a lack of motivation (Tedesco *et al* 1991). Historically, compliance with regular flossing has been far less than ideal and only a minority of patients are compliant flossers (Ciancio 2003). The routine use of dental floss has consistently been shown to be dramatically low (e.g. approximately 7% of the Dutch population flosses on a regular basis). The reasons for this lack of compliance apparently encompass two issues: a lack of patient ability and a lack of motivation (Christou *et al* 1998, Van der Weijden *et al* 2005). Studies are inconsistent in their ability to demonstrate that educational attempts to influence floss frequency can be successful (Asadoorian 2006). 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 (Asadoorian 2006, Segelnick 2004, Stewart & Wolfe 1989). Sniehotta *et al* (2007) provided evidence for the effects of a concise intervention on oral self-care behavior. Other studies have shown that educational attempts to modify client behavior were not successful in improving flossing frequency (Asadoorian 2006, Lewis *et al* 2004). The difficulty in flossing likely makes application of this technique less than universal.

Patient acceptance is a major issue to be considered when it comes to the long-term use of interdental cleaning devices (Warren & Chater 1996). Patient preferences were evaluated in three studies (Christou *et al* 1998, Ishak & Watts 2007, Kiger *et al* 1991). Comparing interdental brushes and dental floss, patients preferred the interdental brushes. The interdental brushes were considered to be simpler to use, despite their tendency to bend, buckle and distort which made the procedure somewhat complicated at times (Ishak & Watts 2007). Interdental brushes were considered to be less time-consuming and more efficacious than floss for interdental plaque removal, which is consistent with previous reports (Bergenholtz & Brithon 1980, Christou *et al* 1998).

Patients need interdental brushes of various sizes. Schmage *et al* (1999) assessed the relationship between the interdental space and the position of teeth. Most interproximal spaces in anterior teeth were small and suitable for the use of floss. Premolars and molars have larger interproximal spaces and are accessible by interdental brushes. Most studies do not discuss the different interdental brush sizes, nor do they indicate if the interdental brushes were used in all available approximal sites. This need to account for different sizes of interdental spaces makes a 'true' random assignment of interdental brushes in clinical trials difficult.

The available studies from the Hoenderdos and coworkers (2008) review show that changes in gingival inflammation, as assessed by the gingival index, are not as apparent as bleeding as an indicator of disease. Numerous studies have shown that sulcular bleeding is a very sensitive indicator of early gingival inflammation. Bleeding following the use of woodsticks can also be used to increase patient motivation and awareness of their gingival health. Several studies have shown the clinical effectiveness of gingival self-assessment (Kallio *et al* 1990, Kallio *et al* 1997, Walsh *et al* 1985). The presence of bleeding provides immediate feedback on the level of gingival health. The dental professional can also easily

demonstrate the gingival condition to the patient by using the interdental bleeding index for this obvious clinical manifestation. This monitoring device may encourage patients to include woodsticks as part of their own oral hygiene regimen (Bergenholtz & Brithon 1980).

Plaque accumulation is greater between molars and premolars than anterior teeth. The wider the interdental space, the more protected the bacterial biofilm will be. Molars and premolars provide the perfect interdental space for bacterial biofilm formation and maturation, without disruption by chewing or toothbrushing. Research has shown powered toothbrushing to have improved efficacy in approximal plaque removal compared with manual toothbrushing (Van der Weijden *et al* 1993, 1994). The findings are based on relatively young study subject and extrapolation to a general population should be undertaken with caution.

Irrigation devices may increase the delivery of fluid beneath the gingival margin (Flemmig *et al* 1990). Greater penetration of a solution into periodontal pockets is achieved by patient-applied supragingival irrigation relative to mouthrinsing (Flemmig *et al* 1995). Studies that evaluated the ability of supragingival irrigation to project an aqueous solution (H_2O or medicinal fluids) subgingivally determined that supragingival irrigation with a standard irrigation tip was capable of delivering H_2O or a medicinal fluid 3 mm subgingivally or to approximately half the probing depth in a 6 mm pocket (Eakle *et al* 1986, Larner & Greenstein 1993). Two studies demonstrated that H_2O irrigation had little effect on the composition of the subgingival flora in sites with pocket probing depths of 4 mm or less (Sanders *et al* 1986, White *et al* 1988). An accessory of an oral irrigator device, the Pik Pocket® subgingival irrigation tip (WaterPik Technologies, Fort Collins, CO, USA), facilitates subgingival penetration of irrigants to 90% of 6 mm pocket depths when placed 1 mm subgingivally (Braun & Ciancio 1992). Supragingival irrigation applies considerable force to the gingival tissues. Irrigation was shown to have the potential to induce bacteremia relative to brushing, flossing, scaling and root planing, and chewing (Carrol & Sebor 1980, Cobe 1954, Felix *et al* 1971, Sconyers *et al* 1973, Silver *et al* 1979, Wampole 1978). Given the collective evidence, it appears that irrigation is safe for healthy patients.

Conclusion

Based on the available literature with respect to interdental cleaning, the best available data suggest the use of interdental brushes. These brushes should therefore be the first choice in patients with open interdental spaces. Meta-analysis showed a superiority of the interdental brush to floss with respect to plaque removal.

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