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Comparison of interdental brush to dental floss for reduction of clinical parameters of periodontal disease: A systematic review

Pauline H. Imai[Δ], DipDH, BDSc(DH), MSc(Dent Sc), RDH; **Xiaoli Yu***, MSc; **David MacDonald**[§], BDS, BSc(Hons.), LLB(Hons.), MSc, DDS(Edin.), DDRRCR, FDSRCPS, FRCD(C).

ABSTRACT

Background: Daily oral biofilm disruption by clients is recommended by oral health professionals to prevent oral diseases and to maintain optimal oral and overall health. Since periodontal diseases and caries are prevalent interproximally, the adjunctive use of interdental aids is highly recommended. **Objectives:** To evaluate the effectiveness of interdental brushing as an adjunct to toothbrushing for the primary outcome of interproximal gingival bleeding and a secondary outcome of interproximal plaque. **Methods:** Only randomized controlled trials were included. Studies were included irrespective of publication status and language. Hand searching was conducted in two peer reviewed journals, with references mined. Pharmaceutical companies that develop and manufacture interdental brushes were also contacted for unpublished or ongoing clinical trials. Sixty-two studies were retrieved from the literature with seven studies meeting the inclusion/exclusion criteria. Forest plots and Chi-square tests were used to determine the presence of heterogeneity. Random effects model, relative risk and 95% confidence intervals were used in the analysis. **Results:** Four studies were included in the meta analysis for bleeding outcome. Although some heterogeneity was present among the studies, the interdental brush groups demonstrated statistical significance for reducing interproximal bleeding compared to the dental floss groups, p = 0.003. Plaque outcomes were analyzed using seven studies, with interdental brush demonstrating statistically significant differences to dental floss, p = 0.024. **Conclusion:** Interdental brush is an effective alternative to dental floss for reducing interproximal bleeding and plaque in clients with filled or open embrasures.

RESUMÉ

Contexte : Les professionnels de la santé buccale recommandent la désorganisation quotidienne du biofilm oral par les clients afin de prévenir les maladies buccales et maintenir la meilleure santé buccale et générale. Vu la prévalence interproximale des maladies périodiques et des caries, on recommande vivement l'utilisation d'appoint d'aides interdentaires. **Objectifs :** Évaluation de l'efficacité du brossage interdentaire comme ajout au brossage des dents pour les résultats primaires du saignement gingival interproximal et un résultat secondaire de plaque interproximale. **Méthode :** Seuls les essais contrôlés et randomisés ont été inclus. Les études ont été inclues indépendamment de la nature de la publication et du langage. La recherche manuelle a été menée par deux journaux revus par les pairs avec une mine de références. Les compagnies pharmaceutiques qui développent et manufacturent des brosses interdentaires ont aussi été consultées sur les essais cliniques non publiés ou en cours. Soixante-deux études ont été retrouvées dans la littérature avec sept études répondant aux critères d'inclusion ou d'exclusion. Les tests Forest plot et Chi-square ont été utilisés pour déterminer la présence d'hétérogénéité. Un modèle d'effets randomisés, de risque relatif et d'intervalles de confiance de 95 % ont servi à l'analyse. **Résultats :** La méta analyse sur le résultat du saignement comprenait quatre études. S'il y avait une certaine hétérogénéité dans les analyses, les groupes de la brosse interdentaire montrèrent des différences statistiquement significatives concernant la réduction du saignement interproximal, comparativement à ceux de la soie dentaire, p = 0,003. L'analyse de la plaque qui en a résulté a fait l'objet de sept études qui notèrent que la brosse interdentaire montrait des différences statistiquement significatives en regard de la soie dentaire, p = 0,024. **Conclusion :** La brosse interdentaire est une alternative efficace à la soie dentaire pour réduire le saignement et la plaque chez les clients ayant des embrasures remplies ou ouvertes.

Key words: oral self care aids, interdental products, gingival bleeding, oral biofilm, plaque index, oral hygiene

INTRODUCTION

Periodontal disease, which is a large family of pathological conditions affecting the supporting structures of the teeth, is a common oral ailment seen in dental hygiene practice.[1] Established oral biofilms, commonly known as dental plaque, cause and exacerbate gingival inflammation.[2–4] If left untreated, periodontal disease may lead to tooth loss.[5]

Periodontal therapy usually consists of professional debridement and client oral self care. Professional scaling and root planing have been shown to reduce the clinical parameters of gingival bleeding and mean pocket depths by removing the subgingival bacterial population and rendering the environment significantly less pathogenic; however, the microflora gradually shift back to a pathogenic supportive environment over three months.[6] Daily oral self care to control the supragingival plaque

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University of British Columbia
* Doctoral student in Statistics
§ Associate Professor & Chairman of the Division of Oral & Maxillofacial Radiology
Correspondence to: Pauline H. Imai; paulineimai@hotmail.com
Δ Dental Program Coordinator, MTI Community College, Vancouver, BC

may assist in slowing or reducing the shift to a pathogenic environment.

Client acceptance of daily toothbrushing is high, but not of dental flossing.[7–9] Toothbrushes are unable to penetrate intact interdental areas,[10,11] where periodontal disease is prevalent,[12] necessitating the use of an interdental device. However, clients do not dental floss daily because it is difficult to use.[13,14] The interdental brush has been identified as a potential, suitable alternative to dental floss for interdental cleansing in other studies because of its ease of use and client acceptance, which may enhance daily compliance.[14,15] Since study results on the effectiveness of interdental brushes have been mixed, a systematic review is needed to provide the oral health clinician with evidence based guidelines.

The purpose of this systematic review is to determine the effectiveness of the interdental brush with toothbrush compared to dental floss with toothbrush in addition to professional debridement for the primary outcome of reducing reducing interproximal gingival bleeding. A secondary clinical outcome, reduction of dental plaque, is also examined since dental plaque is the etiological factor for periodontal diseases.[4] This systematic review will provide the dental hygiene practitioner with evidence based guidelines for recommending oral interdental self care aids to specific clientele for the prevention and treatment of periodontal disease.

Why it is important to do this review

There are many interdental oral self care products available, with dental floss being the most commonly recommended to clients by oral health professionals. However, client compliance with dental flossing is low because it is challenging to use; therefore, it is important to determine the effectiveness of interdental brushes, which have been shown in some studies as being easier to use. Although Slot et al.[16] conducted a systematic review on interdental brushes, the search was restricted to two databases; this review expands the search to include non English databases. The comparison groups in Slot et al.'s review[16] included toothbrushing alone as well as other interdental aids, whereas this review will focus on studies that used toothbrushing with dental floss as a control group to provide clinicians with a direct comparison. The aim of this interdental brush systematic review is to provide oral health professionals and clients with evidence to make informed decisions about their oral health.

OBJECTIVE

The primary objective of this systematic review is to evaluate the effectiveness of interdental brushing as an adjunctive aid to toothbrushing to dental flossing and toothbrushing for the reduction of gingival bleeding, a clinical manifestation of gingivitis. The secondary objective is to evaluate the reduction of dental plaque.

The review focuses exclusively on the comparison of interdental brushes to dental floss, the latter that is often used as the gold standard comparison in periodontal research.[17]

METHODS

Criteria for considering studies for this review

Types of studies

Randomized controlled trials, including split mouth and crossover trials were included. Studies without randomization or those not indicating method of randomization were excluded. Studies were included irrespective of publication status and language.

Types of participants

Participants were adults, 18 years and older, regardless of gender, race, socioeconomic status, geographical location, and setting or time of intervention, presenting with clinical signs of gingivitis and some periodontitis as determined by gingival indices and probing depths. All participants had sufficient sites to accommodate the interdental brushes used in the studies.

Studies were excluded if participants:

1. were taking antibiotics,
2. were taking drugs associated with gingival overgrowth,
3. were taking drugs associated with gingival bleeding,
4. had systemic health conditions such as diabetes, rheumatic fever, hepatic or renal diseases,
5. had orthodontic appliances,
6. and/or were pregnant.

Types of interventions

The review included all studies comparing interdental brush to dental floss as adjuncts to toothbrushing. Studies that used antimicrobial agents such as chlorhexidine or essential oils were included only if data on the control groups, or groups that did not use any antimicrobial agents, were available. Interventions were self performed and were nonsupervised after the initial- and mid-study oral hygiene instructions. Participants were required to use the interdental brush and/or dental floss for a minimum of four weeks to be included in this review. In studies that were longer than four weeks, the final endpoint was included in the analyses.

Types of outcome measures

Primary outcome: Bleeding indices.

Secondary outcome: Plaque indices.

Search methods for identification of studies

A comprehensive search, irrespective of language was conducted *of the literature* from January 1966 to February 2011 to identify relevant studies.

Electronic searches

The following databases were searched for broad coverage of English and non English studies on interdental brushes: National Library of Medicine, Bethesda, USA (PubMed Medline 2006 to 2010), Cumulative Index to Nursing and Allied Health Literature, Ipswich, USA (CINAHL, 1966 to 2010), The Cochrane Collaboration Central Register of Controlled Trials (CENTRAL, 2006 to 2010), Web of Science, New York, USA (1990 to 2010) and LILACS via Bireme, Sao Paulo, Brazil (1982 to 2010).

Searching in each database considered variations in controlled vocabulary and syntax rules. A combination of controlled vocabulary and free text terms were used (see Search terms).

Search terms

The following terms and their variations were used to search the databases:

- For intervention: Interdental brush*, interproximal brush*, proxabrush, proxybrush, interspace brush, oral hygiene products, dental care products, dental devices, dental care, mouth care, oral care, oral self care, oral self care habits, oral hygiene*, oral hygiene methods, oral hygiene equipment, oral hygiene supplies.
- For clinical outcomes: Dental plaque, dental plaque control, dental plaque prevention, dental biofilm, oral biofilm, plaque index, gingival index, bleeding index, clinical attachment loss (CAL), gingivitis, gingivitis prevention, gingivitis control, inflammation prevention, inflammation control, periodontal disease, periodontal disease prevention, periodontitis, periodontitis therapy, clinical effectiveness, clinical efficacy, patient education, patient compliance, patient acceptance.

Other searches

In addition, hand searching was conducted in the *Journal of Clinical Periodontology* from 1974 to 2010 and references were mined from all the studies collected in the searches. Hand searching in the *Canadian Journal of Dental Hygiene* was also conducted from 2005 to 2011 and their references mined. Pharmaceutical companies that develop and manufacture interdental brushes were also contacted for unpublished or ongoing clinical trials.

Data collection and analysis

Selection of studies

Two members of the team independently selected papers based on title and abstract, followed by a full text review to determine whether the paper met the eligibility criteria (Figure 1, Table 1). Any disagreements between reviewers for paper inclusion/exclusion were resolved through discussion. The statistician was consulted in cases of doubt about data extraction and data analysis.

Data extraction and management

Two members of the team extracted data and any disagreements were identified and resolved through discussion. The members were not blinded to the included studies' authors, interventions, or results.

The following data were extracted:

1. Study design, date, and duration of study
2. Participants — sample size, inclusion/exclusion criteria, demographics
3. Intervention — type of floss and interdental brush, duration of intervention, oral hygiene instructions or not, compliance assessment, length of follow up
4. Outcomes — method of assessment, type of indices used, timing of measurement

Additional data such as ethical approval, sample size calculations, inter/intra examiner calibration, and funding sources were extracted.

Risk of bias

Risk of bias was assessed based on sequence generation, allocation sequence concealment, blinding, incomplete outcome data, selective outcome reporting, and other issues. Blinding of examiners was considered important, as participants due to the nature of the comparisons could not be blinded. For crossover designs, further risk of bias assessments included whether the design was suitable for the intervention being studied, the risk of carry over or spill over effects, and appropriate statistical analysis.

Risk of bias data is recorded with the source of information and a judgment of low, high or unclear risk of bias. The assessors were not blinded to the studies' authors, journals or results. Two assessors conducted the risk of bias independently.

Measures of treatment effect

Since the bleeding indices in the included studies were binary measures of bleeding present or absent, risk ratios were used. Plaque indices were ordinal scales, so mean differences were used in statistical tests. Mean and standard deviations are presented for completeness.

Unit of analysis

The participant or groups of measuring sites within individual participants was the unit of analysis.

Missing data

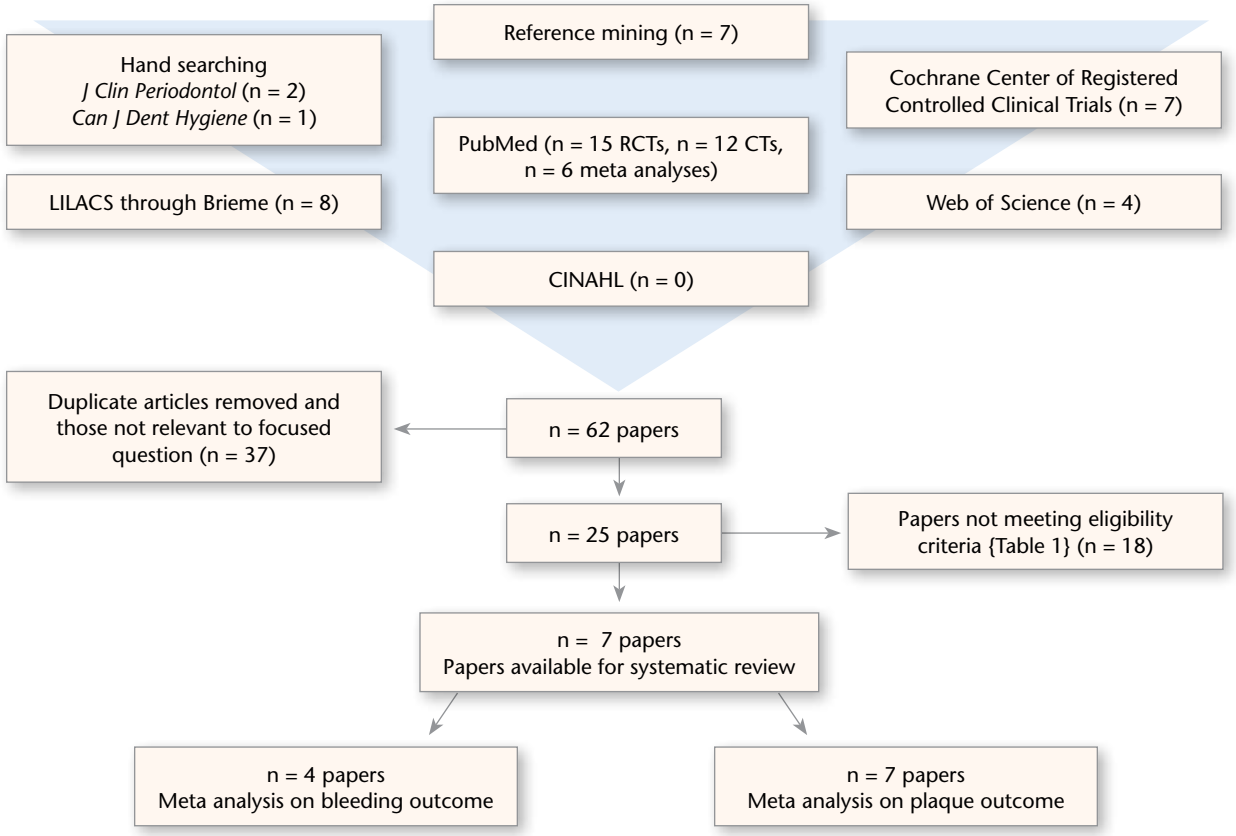
Standard deviations are often missing in summary data, but this did not result in the study being excluded. Where possible, authors were contacted for the missing information. However, if missing data could not be retrieved, then the analysis only included the available data. Potential impact of the missing data is addressed in the Discussion section of the systematic review.

Assessment of heterogeneity

Included studies are assessed for heterogeneity by the type of therapy, control group, and outcomes measured. Studies were descriptively assessed for study design, study length, number of subjects, subjects' age range, subjects' periodontal status, gender, tobacco use, professional debridement prior to intervention phase, and measured clinical outcomes (Table 2).

The use of Forest plots will assist with the assessment of heterogeneity. Studies in the Forest plot graphically demonstrate treatment effects in each study as well as the overall effect determined by the meta analysis. Studies that appear to be homogeneous will be tested by Q test (Chi^2), with a $p < 0.10$ as being interpreted as significant statistical heterogeneity. However, the Q test has low power for identifying heterogeneity if the number of included studies is small. In this situation, the I2 test will be used to determine the magnitude of heterogeneity. A higher percentage indicates that heterogeneity is likely present rather than by chance. For example, 75% to 100% would represent considerable heterogeneity, but 0% to 40% may

Figure 1. Number of papers found in search.



not. Heterogeneous studies are not included in the meta analysis, but are described instead.

Assessment of reporting biases

Bias may occur within study and between studies. Within study bias occurs when the outcomes reported in the published study differ from the outcomes stated in the research protocol or the methods section of the study. Study authors will be contacted in cases of reporting bias for clarification. Depending on the number of included studies (usually more than 10 studies),[18] a funnel plot of effect estimates against their standard errors may be created to determine possible publication bias.

Data synthesis

Only studies with low or unclear risk of bias that report the same outcomes are included in the meta analysis, and a minimum of six studies is required. However, since the test for heterogeneity may not be sensitive enough to detect for heterogeneity, a random effects meta analysis was conducted for robustness. Relative risk and 95% confidence intervals were used in the analysis.

RESULTS

Description of studies

See Table 1 for excluded studies and rationale and Table 2 for brief description of the included studies.

Results of search

The search strategy resulted in 62 potential papers based on titles with or without abstracts (Figure 1). Duplicate papers and papers not relevant to the research question were removed, yielding 25 papers for full text examination. Upon full text examination by two independent reviewers, 18 papers were deemed not meeting the inclusion criteria (Table 1). Some studies had intervention periods of less than four weeks,[19–25] some did not have dental floss as a comparison group,[26–29] others did not have interdental brush as the intervention but instead used toothpicks or brush picks,[11,30,31] one study compared dental floss to rubber tip stimulator and thus, did not have the interdental brush as an intervention,[32] and the remaining studies were reviews.[17,33,34] The final number of studies included in this review was seven (Figure 1). Since the number of studies included was low, a funnel plot was not conducted because there are not enough data points to indicate whether the scatterplot will be symmetrical or asymmetrical.[18]

Included studies

Of the seven studies included, three were parallel RCTs,[35,36] three were split mouth RCTs,[37–39] and one was a crossover design.[14] Two of the parallel RCTs had four[17] or five arms,[36] but data extraction focused on the interdental brush and dental floss arms for this review. The Kiger et al.[14] study, which was a three way crossover, did

Table 1. Studies subsequently excluded on full text examination.

Authors and year	Study design	Reason for exclusion
Bergenholtz, Bjorne, Vikström: 1974	• Crossover • 8 weeks	No interdental brush intervention; toothpicks.
Bergenholtz, Olsson: 1984	• Crossover • 2 weeks per trial	Intervention phase less than 4 weeks.
Galut: 1991	• Literature review	Review; no data available.
Gjermo, Flötra: 1970	• Parallel RCT • 2 to 4 weeks (3 mini RCTs)	Intervention phase less than 4 weeks.
Hofer, Sahrmann, Attin, Schmidlin: 2010	• Split mouth randomized • 1 day	No dental floss comparison; interdental brush used to assess for bleeding only.
Mauriello, Bader, George, Klute: 1987	• Crossover RCT • 3 weeks per trial	Intervention phase less than 4 weeks.
Nayak, Wade: 1977	• Parallel RCT • 2 weeks	No dental floss comparison; rubber cone stimulator instead.
Rösing, Daudt, Festugatto, Oppermann: 2006	• Split mouth RCT • 1 time use	Intervention phase less than 4 weeks.
Rossow: 1992	• Retrospective cohort survey of daily, sometimes, never use	No interdental brush intervention; toothpick compared to dental floss.
Schmage, Platzer, Nergiz: 1999	• Split mouth RCT • 1 week	Intervention phase less than 4 weeks.
Slot, Dörfer, Van der Weijden: 2008	• Systematic review	Review
Tu, Jackson, Kellet, Clerehugh: 2008	• RCT statistical analysis	Exploration of statistical analysis of Jackson et al. paper. Results previously reported.
Vogel, Sullivan, Pascuzzi, Deasy: 1975	• Parallel RCT • 33 days	No interdental brush intervention.
Wærhaug: 1976	• In vitro	No dental floss comparison.
Wolffe: 1976	• Cross over RCT • 1 week per trial	Intervention phase less than 4 weeks.
Wolff, Joerss, Rau, Dörfer: 2006	• In vitro	No dental floss comparison. Comparison of triangular and round interdental brushes only.
Yamamoto, Hasegawa, Sueda, Kinoshita: 1975	• Parallel RCT • 1 week	Intervention phase less than 4 weeks.
Yankell, Emiling: 2002	• Parallel RCT • 4 weeks	No interdental brush intervention; brush picks.

not include washout periods between interventions. Professional debridement prior to the intervention phase varied from none or minimal supragingival scaling to a "thorough" debridement. Participants in all included studies received oral hygiene instructions at baseline and often midway through the study. Participants were instructed to use the interdental brush and dental floss once a day. All studies, except Kiger et al.[14] described participant compliance assessments, which ranged from phone calls, written reminders, self reported logs to amount of product used.

Participants had some level of periodontal disease, ranging from gingivitis to moderate to severe periodontitis. Some studies only included participants who were non-smokers[36,38,39] and two studies identified their participants as smokers or non smokers.[17,35] Except for Yost et al.[17] and Christou et al.[37], female participants outnumbered male participants in the included studies.

Excluded studies

Eighteen articles were removed from the review because they did not meet the inclusion criteria such as intervention phase less than four weeks,[19–25] missing interdental brush intervention,[19,30–32] missing dental floss comparison,[26–29] or study was a review article.[17,33,34] Additional studies were excluded if the risk of bias was high (see Table 3).[17]

Allocation

Allocation or randomization is a mechanism to allocate interventions to participants. Adequate randomization

Table 2. Overview of the studies included in the data analysis.

Authors and year	Methods	Participants	Interventions	
Christou, Timmerman, Van der Velden, Van der Weijden: 1998	• Design: split mouth RCT • Length: 6 weeks • Measurements: Baseline 6 weeks	• Randomized n = 26 • Completed n = 26 • Mean age: 37.4 Range: 27–72 Males and Females = 14 and 12 • Oral health status: Moderate to severe periodontitis, no previous periodontal treatment. Minimum 3 teeth/quad. PD ≥ 5mm, BOP, radiographic bone loss, minimum recession, overt inflammation	• Baseline professional debridement: some supragingival scaling in test sites, but no subgingival scaling • Intervention: interdental brush + toothbrush • Control: waxed dental floss + toothbrush • OHI: hands on and take home written instructions • Compliance assessment: 1 week phone call, 3 week visit to dental hygienist	
Imai, Hatzimanolakis: 2011	• Design: split mouth RCT • Length: 12 weeks • Measurements: Baseline 6 weeks 12 weeks	• Randomized n = 33 • Completed n = 30 • Mean age: 32.3 Range: 19–53 Males and Females = 10 and 20 • Oral health status: Gingivitis Non smokers	• Baseline professional debridement: 2 weeks prior to baseline • Intervention: interdental brush + toothbrush • Control: waxed dental floss + toothbrush • OHI: baseline and week 6, hands on • Compliance assessment: self reported log and product use at weeks 6 and 12	
Ishak, Watts: 2007	• Design: split mouth RCT • Length: 4 weeks • Measurements: Baseline 4 weeks	• Randomized n = 11 • Completed n = 11 • Mean age: 43.6 Range: 33–56 Males and Females = 3 and 7 • Oral health status: Gingivitis to moderate Periodontitis Non smokers	• Baseline professional debridement: supragingival scaling only • Intervention: interdental brush + toothbrush • Control: dental floss + toothbrush • OHI: baseline and hands on and written instructions • Compliance assessment: self reported diary sheet	
Jackson, Kellett, Worthington, Clerehugh: 2006	• Design: parallel RCT • Length: 12 weeks • Measurements: Baseline 6 weeks 12 weeks	• Randomized n = 88 • Completed n = 77 • Mean age: not reported Range: 26–75 Males and Females = 31 and 46 • Oral health status: Chronic periodontitis 29 smokers 48 non smokers	• Baseline professional debridement: scaling for 10 minutes only • Intervention: precurved interdental brush + toothbrush • Control: non shredding dental floss + toothbrush • OHI: baseline and week 6 oral instructions and patient leaflets • Compliance assessment: at 2 weeks, written reminder and at week 6 verbal reinforcement	
Jared, Zhong, Rowe, Ebisutani, Tanaka, Takase: 2005	• Design: parallel RCT, 5 arms • Length: 4 weeks • Measurements: Baseline 2 weeks 4 weeks	• Randomized n = 162 • Completed n = 152 • Mean age: 36.38–42.20 Range: not reported Males and Females = 60 and 92 • Oral health status: Minimum of one interproximal space of 1.0 mm exhibiting bleeding Non smokers	• Baseline professional debridement: none, only rubber cup prophylaxis • Intervention: interdental brush without gel (gp 3) • Control: easy through dental floss + toothbrush (gp 4) • Other Interventions: interdental brush + cetylpyridinium chloride gel + toothbrush (gp 1); interdental brush + placebo gel + toothbrush (gp 2); toothbrush alone (gp 5) • OHI: baseline hands on • Compliance assessment: self reported log and return used/unused materials at weeks 2 and 4	

	Outcomes	Source of funding	Notes
	• Bleeding: BOP to base of pocket with 65 g controlled force probe (PPBI) and • WHO probe along gingival margin at 60° to long axis of tooth (ABI) • Plaque: Volpe modification of Quigley–Hein index • Probing depth: 65 g controlled force probe • Results: interdental brush removes significantly more plaque than dental floss ($p < 0.05$) • Interdental brush significantly reduces probing depths compared to dental floss ($p < 0.05$) • No differences for bleeding	• State scholarships: Foundation of Greece • Enta-Lactona B.V. for toothbrushes and interdental brushes	• Examiner blinded • Type II to III embrasures • Patients reported "more problems with dental floss. Interdental brush felt more efficacious"
	• Bleeding: Eastman bleeding index • Plaque: modification of Silness and Löe • Results: no difference for plaque • Interdental brush significantly better for bleeding reduction compared to dental floss ($p = 0.01$)	• Canadian Foundation for Dental Hygiene Research and Education • Enterprise Dentalink Inc provided the toothbrushes and interdental brushes	• Examiner blinded • Type I to II embrasures • Patients preferred interdental brush "ease of use and convenient"
	• Bleeding: BOP to base of pocket with 0.25 N hinged constant force probe • Plaque: visual examination with confirmation of presence with flossing • Results: no difference for plaque and bleeding	• Oral self care products provided by GlaxoSmithKline, UK	• 10 sites in each quadrant/participant examined by blinded examiner • Type I to III embrasures • Patients prefer interdental brushes because "simpler to use"
	• Bleeding: Eastman bleeding index and BOP • Plaque: modified Silness and Löe • Relative interdental papillae level: occlusal/incisal edge to interdental col of papillae in mm • Results: interdental brush significantly better for plaque reduction ($p = 0.008$) • No difference for Eastman bleeding index at week 12 ($p = 0.07$) and BOP ($p = 0.23$)	• Oral self care products provided by • Colgate-Palmolive: toothbrush, dental floss, toothpaste • Dentsply: dental instruments • Dental Health Boutique, Oral Healthcare, Leatherhead, UK, for interdental brushes	• No control force probe used in BOP • Third molars excluded except where they functioned as second molars • Type II to III embrasures
	• Bleeding: BOP and Van der Weijden modified. Bleeding on marginal probing method • Plaque: Turesky modification of Quigley–Hein index • Gingival: Lobene • Results: no difference for plaque. Interdental brush more likley to reduce bleeding, but not statistically significant	• Study financially supported by Sunstar Inc, Japan, manufacturer of the interdental device	• Participants who had SRP within last month excluded or excessive interproximal calculus • Third molars excluded • Preference for maxillary site versus mandibular site • Type I to II embrasures

Table 2. Overview of the studies included in the data analysis *(concluded)*.

Authors and year	Methods	Participants	Interventions	
Kiger, Nylund, Feller: 1991	• Design: 3 x 1 month cross over Randomized single blind • Length: 12 weeks • Measurements: Baseline 4 weeks after each intervention introduced	• Randomized n = unclear • Completed n = 30 • Mean age: unknown Range: unknown Males and Females = 20 and 10 • Oral health status: perio maintenance pats with open embrasures	• Baseline professional debridement: "thorough prophylaxis" • Intervention: interdental brush + toothbrush • Control: dental floss + toothbrush • Other interventions: toothbrush alone • OHI: baseline detailed oral hygiene instructions • Compliance assessment: none described	
Yost KG, Mallatt ME, Liebman J: 2006	• Design: parallel RCT, 4 arms • Length: 6 weeks • Measurements: Baseline Week 6	• Randomized n = 128 • Completed n = 120 • Mean age: male 35.1, female 39.6 Range: male 19–57, female 18–63 Males and Females = 37 and 83 • Oral health status: Minimum mean plaque index 1.5 Minimum mean gingival index 1.0 Able to floss 108 non smokers 12 smokers	• Baseline professional debridement: prophylaxis to remove supragingival calculus and plaque • Interventions: G-U-M Go-Betweens (interdental brush) • Controls: dental floss • Other interventions: flossers soft picks • OHI: baseline instruction and supervision • Compliance assessment: self reported diary checked at week 3	

occurs when a participant has an equal chance of being placed into the intervention or control group regardless of the examiner's preference and/or participant's characteristics. Examples of adequate randomization methods are using computer generated random number lists, coin toss, or throwing dice. The randomization process should be clear and detailed to reduce potential selection bias of participants into specific study arms. Jackson et al.[35] and Imai and Hatzimanolakis[15] had clearly identified the randomization process, but the remaining studies were unclear in spite of stating the sequence allocation was randomized among the participants.

Allocation concealment, which refers to the method used to implement the sequence such that foreknowledge of next allocation is unknown was adequate in two studies,[38,39] unclear in three studies,[14,35,36] and not done in the remaining two studies.[17,37]

Blinding

An examiner and/or participant is considered "blinded" when it is unknown whether the participant is in the experimental or control group. Blinding the examiner and participant reduces potential bias, especially when the study measurements are subjective, such that one cannot interpret results in a manner that one thinks or hopes should be occurring. In periodontal studies, gingival and plaque indices are subjective interpretations of data observed by the examiner. For example, if an examiner believes intervention A is better than B, there may be intentional or unintentional subjective interpretation of the gingival colour, contour, consistency, texture, amount of bleeding and plaque on the tooth with sites treated by product A performing better than those by B. Lack of examiner blinding may have undue influences on the study results.

In six studies,[14,17,35,37–39] the examiner was blinded, which reduced the examiner bias for collecting and interpreting the bleeding and plaque scores. Although Jared et al.[36] stated the study was single blinded, there are no details as to how they kept the examiner blinded. It was not possible to blind the participants due to the different design of the oral self care products, but this may not have affected the bleeding and plaque indices as compliance for both products was high in the studies.[14,17,35,37–39]

Incomplete outcome data

Incomplete data refer to participants who drop out of the study and data exclusions from the statistical analyses. To reduce bias, one must consider the reasons for the dropouts. For example, a participant moving away would be considered a justifiable reason, and would not adversely affect the study in terms of bias compared to a participant who withdrew because of adverse effects from the intervention.

Reasons for loss of follow up or exclusion of data from analyses were provided in five studies,[35,36,37–39] but were missing or unclear in two studies.[14,17] In the Kiger et al.[14] study, data were missing on soft tissue trauma and loss of tooth substance among groups and it was unknown if dropouts occurred. In regards to our review, this would not have significant effects on the comparison of interdental brush to dental floss outcomes. The Yost et al.[17] study was missing standard deviations in the results and the contacted author was unable to provide them. Eight participants withdrew after randomization in the Yost et al.[17] study, but there are no details for the withdrawl. In the other five studies,[35–39] loss of participant follow up was usually due to participants beginning antibiotic therapy or for health or family related issues, which were not product related, and thus, would not impact the study outcomes.

	Outcomes	Source of funding	Notes
	• Bleeding: not measured • Plaque: Turesky modified Quigley–Hein (1970) and Wolffe index (1976) • Gingivitis: Löe and Silness (1965) • Soft tissue trauma: Weaks (1984) • Loss of tooth substance: Lie and Meyer (1977) • Results: interdental brush statistically signficantly better than dental floss for interproximal plaque reduction (p = 0.0208)	• Study supported by Oral-B laboratories, manufacturer of products	• Sites as unit of analysis • Type III embrasures • No wash out period • Patients find "dental floss more difficult and technically demanding in spite of repeated instructions. Interdental brush easier and more comfortable"
	• Bleeding: Eastman bleeding index • Plaque: Benson modification of Quigley–Hein index • Gingivitis: Silness and Löe gingival index • Other: soft tissue examination, no details provided • Results: no statistical difference for Eastman bleeding and plaque indices	• Study supported by Sunstar Americas, manufacturer of the products tested	• Participants with minimum of mild gingivitis, but having at least 5 embrasures that will accommodate interdental brush

Selective reporting

Selective reporting is when authors choose to publish outcomes based on the identified best results creating potential bias in the results' interpretations. For example, choosing the best time point to report the positive result and failing to discuss the other time points, choosing analyses that support a positive outcome such as final end point comparison of products (X vs Y) versus change from baseline to end point for each product (X changed from baseline to end point and Y changed similarly, but there is no direct comparision of X to Y at endpoint), or collecting data but not reporting it. To assess possible selective reporting, published studies were compared to their published protocols and missing data that appeared to be collected were clarified with the authors.

Five studies[35–39] were considered low risk for bias in regards to selective reporting as they reported the results mentioned in the study's methods. The sixth study, by Kiger et al.[14] mentioned that soft tissue trauma and loss of tooth substance was evaluated, but there were no statistical tests conducted nor quantitative results provided, that may possibly indicate selective reporting. However, Kiger et al.[14] provided means and standard deviations for the plaque scores and so this study was included for the plaque analysis. Similarly, Yost et al.[17] mentions a soft tissue examination in the methods section, but does not follow up with any outcomes in the results section. The contact author for the Yost et al.[17] study was unable to provide the soft tissue data.

Other risk of bias

Other potential sources of bias that may influence the study results are inappropriate influence of funders, inappropriate co-interventions, cross contamination such as lack of washout period for crossover studies, and unbalanced baselines across groups. Although many studies received some in-grant support from pharmaceutical companies such as receiving complimentary products for the trial, it was not clear in some studies[14,17,36] whether there was undue influence as some of the authors were affiliated with the pharmaceutical company. The other four studies[35,37–39]stated the authors had no affiliation with the pharmaceutical company and/or were supported through independent grants.

Effects of intervention

Bleeding

Bleeding is a clinical sign of active gingival inflammation and was an assessed outcome in six studies.[17,35–39] The bleeding score was determined by probing to the base of the pocket with a force controlled probe,[35,37,39] stimulating the gingival margin at a 60 degree angle using the probe,[36,37] and/or using a wooden toothpick inserted four times horizontally into the interproximal area as in the Eastman Bleeding Index.[17,35,38]

Since the Yost et al.[17] study did not include standard deviations, it was removed from further statistical analyses. The Jared et al.[36] study was also removed from further statistical analyses since the bleeding scores were given in frequencies and raw scores could not be verified. The bleeding outcome measurements in Ishak and Watts[39] were clarified by contacting the corresponding author. The bleeding scores were based on the presence or absence of bleeding in 10 sites per side of mouth (the study was split mouth) and the statistical unit was sites.

In the remaining studies (Table 4), Christou et al.[37] did not report any statistical difference between interdental brush and dental floss at six weeks, but instead noted that both products reduced bleeding over time. In contrast, Jackson et al.[35] demonstrated statistically significant

Table 3. Risk of bias.

Study and Risk of Bias (Low, High, Unclear)	Item	Judgment	Description
Christou, Timmerman, Van der Velden, Van der Weijden: 1998	Adequate sequence generation?	Unclear	"…use of dental floss was randomly assigned to the left or right half of the mouth and the use of interdental brush to the other side."
Risk of bias: Low	Allocation concealment?	No	No indication of how sequence was implemented to ensure that randomization was not contrived.
	Blinding? Researcher assessed outcomes	Yes	"Performed in absence of the examiner, keeping these recordings blind throughout the study."
	Blinding? Self reported outcomes	No	Level of comfort, perception of efficacy, and any problems reported by participants who were not blinded.
	Incomplete outcome data addressed?	Yes	No loss to follow up. Sites not accessible for interdental brush and dental floss were excluded from analysis.
	Free of selective reporting?	Yes	All outcomes stated in Methods section were addressed in Results. No protocol available.
	Free of other bias?	Yes	Independent grant to fund study. Enta-Lactona supplied toothbrush and interdental brush.
Imai, Hatzimanolakis: 2011	Adequate sequence generation?	Yes	"Randomization of products to left or right side of mouth was determined by a flip of coin by the study organizer."
Risk of bias: Low	Allocation concealment?	Yes	Randomization by coin flip, such that interdental brush assigned to either left or right side of mouth.
	Blinding? Researcher assessed outcomes	Yes	"Only the examiner, who was unaware of the product randomization throughout the study, collected the clinical measurements at baseline, 6, and 12 weeks."
	Blinding? Self reported outcomes	No	Self reported compliance log by non blinded participants.
	Incomplete outcome data addressed?	Yes	Reasons for loss of follow up "moderate to severe periodontitis, not enough bleeding sites, too many missing teeth, require premed antibiotics, no longer interested, family emergency, began antibiotic therapy during study."
	Free of selective reporting?	Yes	All outcomes stated in Methods reported in Results. Study followed research protocol.
	Free of other bias?	Yes	Research grant from CFDHRE; toothbrush and interdental brush supplied through intermediary distribution company.
Ishak, Watts: 2007	Adequate sequence generation?	Unclear	"…use of interdental brush was randomly assigned to left or right half of the mouth." "For left-handed subjects, the random assignation was reversed to allow for any effect on manipulation."
Risk of bias: Low	Allocation concealment?	Yes	"A statistician who was not directly involved in recruiting patients generated the randomization sequence."
	Blinding? Researcher assessed outcomes	Yes	"All measurements were carried out at baseline and one month by one experienced examiner (TW), who was blinded."
	Blinding? Self reported outcomes	No	Self reported diary and questionnaire.
	Incomplete data addressed?	Yes	No loss to follow up.
	Free of selective reporting?	Yes	All outcomes stated in Methods were reported in Results. No protocol available.
	Free of other bias?	Yes	All materials supplied by GlaxoSmithKline, UK, so no preference of interdental brush over dental floss and researchers based in Kings College, Dental Institute London.

Table 3. Risk of bias *(continued)*.

Study and Risk of Bias (Low, High, Unclear)	Item	Judgment	Description
Jackson, Kellett, Worthington, Clerehugh: 2006	Adequate sequence generation?	Yes	Computer generated random numbers and 4 allocation envelopes labelled for gender and smoking habit.
Risk of bias: Low	Allocation concealment?	Inadequate	4 allocation envelopes labeled for gender and smoking habit.
	Blinding? Researcher assessed outcomes	Yes	"Patients were randomly allocated to floss or interdental brush group by research assistant…At all times, the hygienist examiner was unaware of the group to which the patient was allocated."
	Blinding? Self reported outcomes	Unclear	Not reported.
	Incomplete outcome data addressed?	Yes	Reasons for loss to follow up given. "Not have the required number of sites…Prescribed antibiotics during study…failure to complete 3 visits, periodontal-endodontic lesion requiring emergency treatment…." Not likely to affect results.
	Free of selective reporting?	Yes	No protocol available. All outcomes stated in Methods reported in Results.
	Free of other bias?	Yes	Dental equipment and oral self care products supplied by 3 different companies, which the authors have no affiliation.
Jared, Zhong, Rowe, Ebisutani, Tanaka, Takase: 2005	Adequate sequence generation?	Unclear	Block randomization based on baseline dental plaque scores.
Risk of bias: Unclear	Allocation concealment?	Unclear	No indication of how block randomization done to implement sequencing of allocation.
	Blinding? Researcher assessed outcomes	Unclear	"Single blind" No details on how they kept the single examiner blinded.
	Blinding? Self reported outcomes	No	Self reported logs of number of times using product, if cleaning deviated from group to which they were assigned, and details of any symptoms experienced by some groups who were not blinded. Only blinding in the two groups testing interdental brush with active and placebo gels.
	Incomplete outcome data addressed?	Yes	Loss of follow up "9 withdrew prior to baseline and one dismissed due to health issues. None were product related." Unlikely to affect results. Bleeding in percentage, no mean or standard deviation.
	Free of selective reporting?	Yes	No protocol available. All outcomes stated in Methods reported in Results.
	Free of other bias?	Unclear	3 of the 6 authors are affiliated with Sunstar Inc, Japan, which provided "generous financial support" for the research.
Kiger, Nylund, Feller: 1991	Adequate sequence generation?	Unclear	"…each subject received…random assignment to one of three treatment groups by a separate investigator." No indication of how sequence generation done.
Risk of bias: Unclear	Allocation concealment?	Unclear	"…assignment to one of three treatment groups by a separate investigator." No indication of how this was done.
	Blinding? Researcher assessed outcomes	Yes	"Clinical examiner had no knowledge of which study group patients were assigned to at any time."
	Blinding? Self reported outcomes	No	No indication of self reporting, but nature of products precludes subject blinding.
	Incomplete outcome data addressed?	No	Missing data on soft tissue trauma and loss of tooth substance among groups; only descriptive information. Unknown if dropouts occurred.
	Free of selective reporting?	No	No indication of statistical parameters, e.g., alpha and beta levels set apriori, total number of sites, confidence intervals.
	Free of other bias?	Unclear	Industry supported study. No wash out periods between interventions.

Table 3. Risk of bias *(continued)*.

Study and Risk of Bias (Low, High, Unclear)	Item	Judgment	Description
Yost, Mallatt, Liebman: 2006	Adequate sequence generation?	Unclear	"…randomly assigned to one of the four test products…"
Risk of bias: High	Allocation concealment?	No	No indication of who assigned subjects to each group and how this was done.
	Blinding? Researcher assessed outcomes	Yes	"The subjects used their assigned product in a separate area to maintain examiner blinding…"
	Blinding? Self reported outcomes	No	Self reported diary of compliance.
	Incomplete outcome data addressed?	Unclear	"…128 meeting all the study criteria to be enrolled and randomized. …8 subjects dropped after randomization with remaining 120 completing the study." No details on loss of follow up subjects. Missing standard deviations in Tables; can only estimate on bar graphs. Request sent to corresponding author for standard deviation.
	Free of selective reporting?	No	Oral soft tissue examination not found in Results section, but mentioned in Methods. No protocol available.
	Free of other bias?	No	No indication of smokers distribution within the 4 groups, which may affect bleeding and gingivitis indices. Statistical tests used are unsuitable. Industry supported study.

differences between interdental brush and dental floss at week six ($p < 0.05$), but these differences failed to reach significance at week 12 ($p = 0.07$). Imai and Hatzimanolakis[15] demonstrated that the interdental brush reduced bleeding better than dental floss at week six, $p = 0.035$, and at week 12, $p = 0.001$ for bleeding interproximal sites, but post hoc analyses at the subject level indicated that interdental brush was better than dental floss for bleeding reduction only at week 12, $p = 0.01$.

Although the Forest plot into the effects of bleeding had overlapping confidence intervals, the test of heterogeneity of the studies, $I^2 = 59.72\%$ and Q (df = 3) = 8.1308 with $p = 0.0434$ (Figure 2), which is statistically significant, indicated there may be heterogeneity present among the studies. However, a meta analysis was conducted using the random effects model, which is considered robust enough to identify statistical significance. For the bleeding outcome, the random effects model with a corresponding estimate of the treatment effect being 0.08, $p = 0.003$ indicated that interdental brushes reduced the bleeding index scores compared to dental floss.

Plaque

Dental plaque was assessed in seven studies[14,17,35–39]; however, different plaque indices were used (Table 5). Most plaque indices were ordinal scales, but varied in number of categories. There were three modifications of the Quigley and Hein index: Volpe modification,[37] Turesky modification,[14,36] and Benson modification;[17] and two studies used modified Silness and Löe.[35,38] Ishak and Watts[39] simply counted the number of sites that presented with disclosed plaque as determined by its presence on dental floss.

Results for plaque outcome varied across the studies. Four studies demonstrated statistically significant differences between interdental brush and dental floss for plaque reduction[14,35–37] and the other three included studies did not.[17,38,39]

Since the forest plots indicated that the studies were homogeneous as demonstrated by the overlapping confidence intervals, the $I^2 = 34.26\%$, and the Q (df = 5) = 6.4860, $p = 0.2618$ (Figure 3), a meta analysis was conducted. The random effects model with corresponding estimate of treatment effect of 0.13 yielded a p-value of 0.024 indicating the statistically significant reduction in plaque index scores for interdental brush as compared to dental floss.

DISCUSSION

Summary of main results

The meta analyses for bleeding and plaque outcomes indicate that the interdental brush is better than dental floss for reducing bleeding and plaque between 4 and 12 weeks.

Overall completeness and applicability of evidence

The literature was searched broadly up to early 2011 to include all randomized clinical human trials comparing interdental brush to dental floss with a minimum of a four week intervention phase to provide evidence for oral health practitioners and clients/patients. Pharmaceutical companies that develop and market interdental brushes and dental floss were also contacted as possible sources of unpublished studies.

Table 4. Bleeding index at the end of each study.

Study	Interdental brushes			Dental floss			Mean difference (SD)
	n (Subjects)	Mean	Standard deviation	n (Subjects)	Mean	Standard deviation	
Christou et al.: 1998	26	0.83	0.18	26	0.86	0.15	0.03 ± 0.05
Jackson et al.: 2006	43	0.1	0.11	44	0.16	0.17	0.06 ± 0.03
Ishak et al.: 2007	10	5.6	4.79	10	8.1	5.06	2.5 ± 2.2
Imai, Hatzimanolakis: 2011	30	0.08	0.02	30	0.2	0.04	0.12 ± 0.01

Table 5. Plaque index at end of each study.

Study	Interdental brushes			Dental floss			Mean difference (SD)
	n (Subjects)	Mean	Standard deviation	n (Subjects)	Mean	Standard deviation	
Christou et al.: 1998	26	2.15	0.99	26	2.47	0.86	0.32 ± 0.26
Jackson et al.: 2006	43	0.72	0.37	44	0.96	0.40	0.24 ± 0.08
Jared et al.: 2005	30	2.02	0.77	29	2.23	0.83	0.21 ± 0.21
Ishak et al.: 2007	10	6.7	2.36	10	8.1	3.84	1.4 ± 1.43
Kiger et al.: 1991	30	0.51	0.28	30	0.62	0.33	0.11 ± 0.08
Imai, Hatzimanolakis: 2011	30	1.26	0.24	30	1.28	0.22	0.02 ± 0.06

Quality of evidence

Quality of evidence was fair to good with studies having blinded examiners to reduce subjective data collection, generating adequate allocation of subjects to experimental groups, addressing incomplete data, and being relatively free of selective reporting. Any affiliation or in-grant aid from pharmaceutical companies were disclosed and explained such that it is unlikely that the manufacturers of the dental products had significant influence on the study results interpretation.

Potential biases in review process

The team consisted of members who could read other languages as well as colleagues who could be called upon to interpret studies published in languages other than English, which reduced potential study selection bias during the searching and eliminating processes. However, the potential risk of publication bias, in which only positive results papers are published, is present. The team members are not affiliated with any dental product manufacturer or pharmaceutical company and thus, do not have a vested interest in a specific outcome for this systematic review. One author included a study of her own, but the other authors independently assessed the study for inclusion/exclusion and risk of bia assessments and the study was subsequently included in the systematic review.

Agreements and disagreements with other studies and reviews

In the literature, the bleeding and plaque outcomes varied from no statistically significant difference between interdental brush and dental floss to statistical significance. For example, the systematic review by Slot et al.[16p.258,261] did not demonstrate statistically significant differences between interdental brush and dental floss for gingival bleeding reduction, but this review did. Slot et al.[16] included studies that used the interdental brush only once, as well as other interdental aid comparisons compared to this review which only focused on comparisons between interdental brush and dental floss that had been used for a minimum of four weeks by the participants. Single use interventions may not allow the gingival tissues enough time to heal and thus, revert to non bleeding status.[6]

The differences in individual study results may be attributed to differing study designs and protocols. For example, studies[17,35–37,39] that did not include professional debridement and/or only supragingival scaling prior to the intervention phase did not demonstrate differences between interdental brush and dental floss for the bleeding indices. Subgingival calculus is associated with increased gingival bleeding;[40] therefore, it may be hypothesized that the effect of subgingival calculus on gingival health overshadowed the beneficial effects of interdental oral self care by the participants and any small differences between the products' efficacy. For example, Imai and Hatzimanolakis[15] performed supra- and sub-gingival debridement on all participants, and thus, the results demonstrated that the interdental brush was statistically significantly better than

Figure 2. Forest plot for bleeding index.

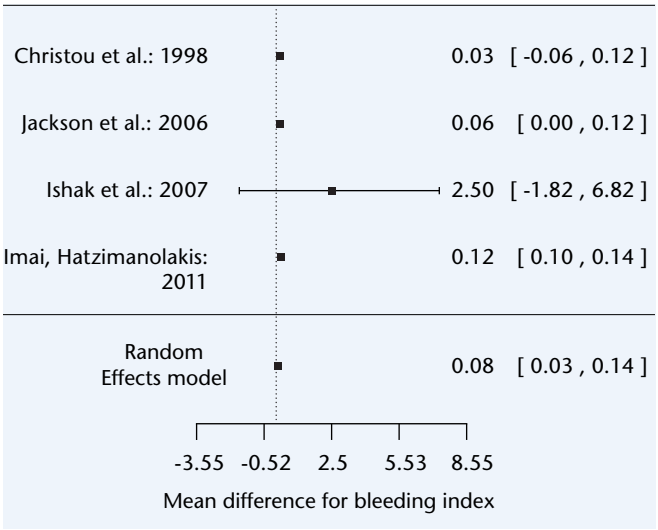
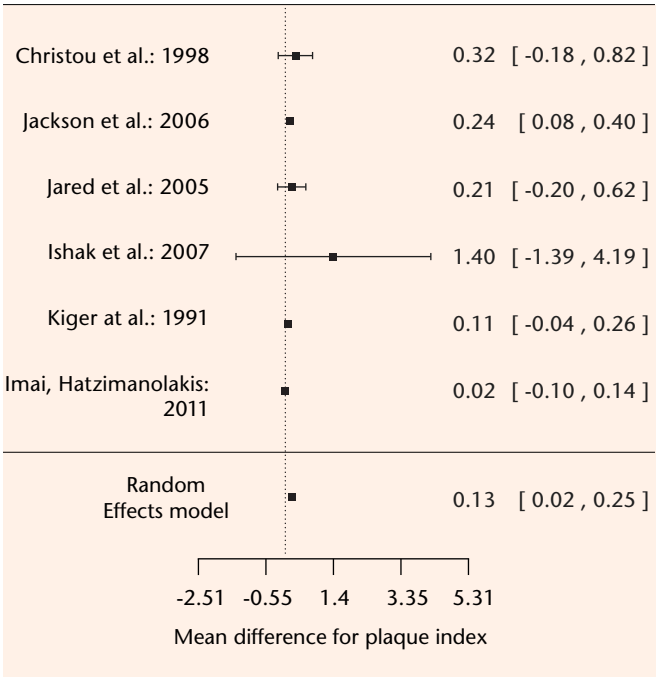


Figure 3. Forest plot for plaque index.



dental floss for bleeding reduction compared to Christou et al.[37] that only provided supragingival scaling and found no differences between the products.

The variation in plaque outcomes may be attributed to the participants' gingival health status. In studies[17,36,38,39] with participants that had gingivitis to moderate periodontitis—and thus, possibly smaller embrasure spaces—the plaque outcomes were not significantly different between interdental brush and dental floss. In comparison, participants with severe and/or chronic periodontitis—and thus, anticipated larger embrasure spaces—demonstrated statistically significant differences for plaque reduction with the interdental brush outperforming dental floss.[14,35,37] As periodontium support is lost through progressive periodontal disease, the invaginated interproximal root surfaces are exposed. Appropriatedly selected interdental brushes fill the embrasure space and extend their bristles into the invaginated surfaces; thus, removing and disrupting the interproximal oral biofilm unlike dental floss which only disrupts plaque on the line angles.[19,28,41–43] In the Slot et al.[16] review, it was concluded that the interdental brush had higher plaque reductions than dental floss; however, this was only noted with two studies using the Silness and Löe plaque index, one study of which used the interdental brush once on each participant. In this current review, the same study[35] as that used in Slot et al.'s[16] review showed positive results with interdental brush over dental floss using the Silness and Löe plaque index. In addition, this review found that Christou et al.[37] and Kiger et al.[14] which used a modification of Quigley and Hein plaque index, also demonstrated interdental brush superiority. In all three studies, the participants had large, open embrasures and therefore, it is proposed that it is not the plaque index that is influencing the plaque outcomes, but rather the participants' oral anatomy.

CONCLUSIONS

Implications for practice

Interdental self care is important for disrupting the oral biofilm and maintaining oral health. Although dental flossing is a common interdental cleansing method for clients with type I embrasures, where interdental papilla fill the interdental space, its effectiveness is dependent on the client's technique and motiviation to floss daily.[44] Motivation is closely linked to the client's perceptions of a product's ease of use.[44] Oral self care techniques that are easy to perform are more likely to be implemented in a daily routine than techniques that require significant dexterity and effort to achieve results.[44]

Interdental brushes were preferred by study subjects because it was easier to use.[14,37–39] Although the interdental brush was noted to bend and buckle, study participants preferred the one handed method and time efficiency compared to the efforts required for dental flossing.[14,37–39]

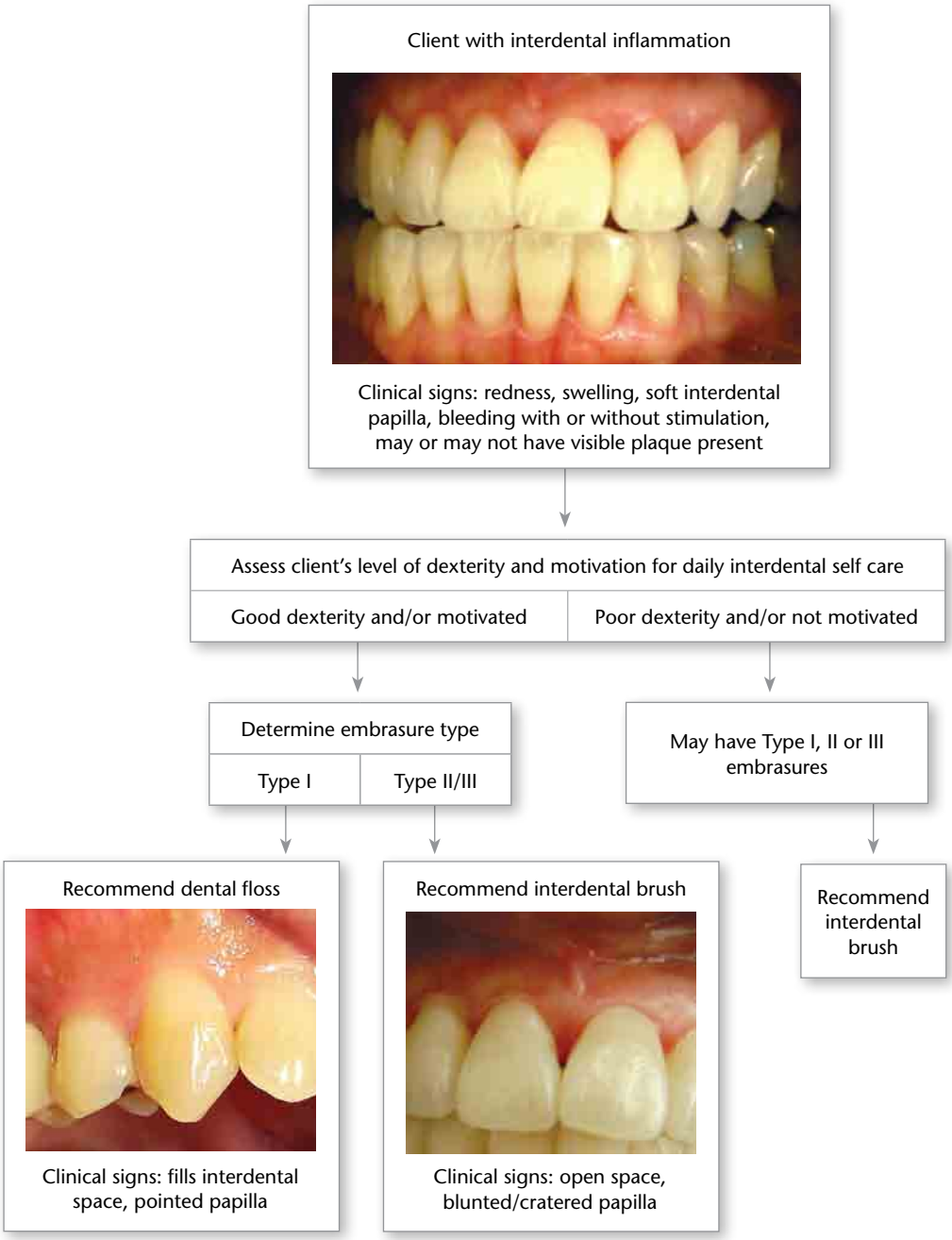
In the past, interdental brushes were available only in large diameters and were thus, suitable for clients with open embrasures. However, the newer interdental brushes are available in diameters that can be accommodated in most type I embrasures.[15] This systematic review supports the interdental brush as an effective alternative to dental floss for clients with interproximal gingival inflammation, and provides the oral health clinican with evidence based guidelines to support oral self care recommendations for their clients (Figure 4).

Implications for research

Further research is needed to:

- Develop an accurate and reliable dental plaque index for assessing interproximal plaque, especially in type I embrasures where visibility is limited and for incorporating the recent developments in oral biofilm maturation and its effects on gingival inflammation.

Figure 4. Practice guidelines for the client with interdental inflammation.



- Investigate other interdental aids' effectiveness in type I embrasures as viable alternatives to dental floss for clients who lack dexterity.
- Study long term compliance and effectiveness of interdental aids to address the Hawthorne Effect on the short term results and observe hard and soft tissue adverse effects.

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Declarations of interest

The authors are not affiliated with any dental product or pharmaceutical company.

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