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REVIEW ARTICLE

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The effect of sugar-free chewing gum on plaque and clinical parameters of gingival inflammation: a systematic review

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Abstract: *Objective:* The aim of this study was to systematically review the current literature on the clinical effects of sugar-free chewing gum on plaque indices and parameters of gingival inflammation. *Material and methods:* The MEDLINE-PubMed, Cochrane-CENTRAL and EMBASE databases were searched up to 20 April 2012 to identify any appropriate studies. Plaque indices and parameters of gingival inflammation were selected as outcome variables. *Results:* An independent screening of the 594 unique titles and abstracts identified six *non-brushing* and four *brushing* studies that met the eligibility criteria. In the *non-brushing* studies, the use of chewing gum did not significantly affect the parameters of interest. In the descriptive analysis of the *brushing* studies, four of five comparisons showed a statistically significant effect in favour of the sugar-free chewing gum with respect to plaque scores. The meta-analysis for the Quigley & Hein (*J Am Dent Assoc* 1962; 65: 26) plaque index scores in the *brushing* studies also showed a significant difference (DiffM −0.24, 95% CI [−0.41; −0.08]). For bleeding tendency, the descriptive analysis showed that one of the two comparisons identified a significant difference in favour of chewing gum. The meta-analysis, however, did not substantiate this difference. *Conclusion:* Within the limitations of this systematic review, it may be concluded that the use of sugar-free chewing gum as an adjunct to toothbrushing provides a small but significant reduction in plaque scores. Chewing sugar-free gum showed no significant effect on gingivitis scores. In the absence of brushing, no effect on plaque and gingivitis scores could be established.

Key words: chewing gum; gingival inflammation; meta-analysis; plaque; sugar-free; systematic review

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Introduction

The chewing of non-food items and gummy substances for pleasure can be traced back to ancient Greek culture and later throughout the Middle East, as well as among Mayan Indians in the early centuries A.D. Chewing gum is commonly thought of as being a part of American culture, and it was popularized in Europe during World War II when it was included in US Army rations. Currently, chewing gum is a multibillion-dollar industry worldwide, with more than a half million tons used annually. Chewing gum is a well-accepted, enjoyable and frequent activity for

adults and children, although most consumers of chewing gum are teenagers (1, 2).

Chewing gum consists of a gum base, sweetener, flavouring and aromatic agent. Historically, commercially available chewing gum was sweetened with sugar (sucrose) and contributed to dental caries (1). Today, most chewing gums sold in Europe are sweetened with sugar substitutes. The predominant sugar substitutes are polyols, which are low-caloric substances sometimes called 'sugar alcohols' because their chemical structure is similar to that of both sugar and alcohol. The most common polyols in sugar-free chewing gum are sorbitol, which is a hexatol derived from glucose, and xylitol, which is a pentatol that occurs widely in nature (3, 4).

Imfeld (2) suggested that sugar-free chewing gum has no relevant mechanical tooth-cleaning effects, although the saliva stimulated by mastication will effectively dissolve and remove soluble fermentable substrates from the oral cavity, increase the pH of plaque and promote the remineralization of early carious lesions. The use of sugar-free chewing gum as a mechanical salivary stimulant after eating can accelerate the clearance of dietary substances and micro-organisms, promote the generation of buffers to neutralize plaque acids and provide antibacterial substances (5). The chewing of sugar-free gum after meals and the consumption of carbohydrate-containing snacks is strongly recommended if no mechanical oral hygiene can be performed. Little evidence has been found to indicate that chewing gum reduces gingivitis or is effective in removing plaque; chewing gum *per se* is neither a substitute for nor an important adjunct to traditional mechanical oral hygiene (2). Other investigators using various forms of market-available chewing gums have reported increases in salivary pH as well as reductions in dental plaque and gingivitis (6–8).

A systematic quantitative evaluation has not yet been performed on the clinical effects of sugar-free chewing gum on plaque and parameters of gingival inflammation. Therefore, this paper systematically evaluated the current literature to add 'evidence-based' knowledge concerning the effects of sugar-free chewing gum use. In particular, this systematic review focused on comparisons with no chewing gum as a control.

Materials and methods

This systematic review was conducted in accordance with the guidelines for the Transparent Reporting of Systematic Reviews and Meta-Analyses (PRISMA-statement) (9).

Focused PICO question

In adults, what is the clinical effect of chewing sugar-free gum compared with not chewing gum on plaque indices and parameters of gingival inflammation?

Search strategy

Three internet sources were used to search for appropriate papers that satisfied the study purpose. These included the National Library of Medicine, Washington, DC (MEDLINE-PubMed), the Cochrane Central Register of Controlled Trials (CENTRAL) and EMBASE (Excerpta Medical Database by Elsevier). For this comprehensive search, all three databases were searched for eligible studies included in the database up to 20 April 2012. The structured search strategy was designed to include any published paper that evaluated the effect of chewing gum on plaque and the parameters of gingival health. For details regarding the search terms used, see Box 1.

Box 1

Search terms used for PubMed-MEDLINE, Cochrane-CENTRAL and EMBASE. The search strategy was customized according to each database that was searched.

The following terms were used in the search strategy:

({intervention} AND {outcome/disease})

({*Intervention:*<[MeSH terms/all subheadings] Chewing Gum OR [text words] Chewinggum OR Chewinggums OR Chewing-gum OR Chewing-gums OR Gum-chewing OR Bubblegum OR Bubblegums OR Bubble-gum OR Bubble-gums>

OR

<(Chewing OR chew OR bubble) AND (Gum OR gums)>}

AND

{*Outcome/disease:* <[MeSH terms/all subheadings] Gingival Pocket OR Periodontal Pocket OR Periodontal Diseases OR gingival hemorrhage OR gingivitis OR [text words] gingivitis OR gingivit* OR gingival bleeding OR gingival hemorrhage OR gingival diseas* OR gingival index OR gingival inflammation OR bleeding on probing OR papillary bleeding OR bleeding index OR sulcus bleeding index OR Periodontitis OR pocket depth OR Gingival Pocket OR Periodontal Pocket OR Periodontal Diseas* OR pockets OR probing depth OR probing-depth OR probing-pocket-depth OR probing pocket depth OR pocket-depth OR periodontal attachment loss OR plaque index OR dental plaque OR plaque OR interdental plaque OR interproximal plaque OR dental deposit* OR stain OR discoloration OR calculus OR tartar>})

The asterisk (*) was used as a truncation symbol.

The eligibility criteria were as follows:

- Randomized controlled clinical trials (RCTs) or controlled clinical trials (CCTs).
- Manuscripts written in the English language.
- Conducted in humans.
- Subjects $\geq$18 years of age and without orthodontic appliances or (partial) dentures (ADA) (10).
- Intervention group: sugar-free chewing gum (sweetened with xylitol or sorbitol, and without any specific active/therapeutic ingredients).
- Control group: not using chewing gum.
- Clinical parameters: plaque scores and gingivitis scores.

Screening and selection

Two reviewers (GAW and RSK) independently screened the titles and abstracts for eligible papers. If the eligibility aspects were present in the title, the paper was selected. If none of the eligibility aspects were mentioned in the title, the abstract was read in detail to screen for suitability. When the abstract was not

clear but the title seemed to be relevant, the paper was selected for full-text reading. If no abstract was available but the title contained the eligibility criteria, the paper was also selected for full-text reading. After selection, the full-text papers were read in detail by two reviewers (GAW and RSK). Any disagreement between the two reviewers was resolved after additional discussion. If a disagreement persisted, the judgment of a third reviewer (DES) was decisive. Papers that fulfilled all selection criteria were processed for data extraction. All reference lists of the selected studies were hand-searched by two reviewers (DES and RSK) for additional published work that could possibly meet the eligibility criteria of the study.

Assessment of heterogeneity

The heterogeneity across the studies was determined according to the following factors:

- Study design.
- Subject characteristics.
- Intervention and regimen.
- Clinical indices.
- Funding source.

Quality assessment

Two reviewers (DES and RSK) scored the methodological qualities of the included studies. The methodological study quality was assessed according to the RCT checklist of the Dutch Cochrane Center (11) and according to quality criteria that were obtained from the CONSORT statement (12), Moher *et al.* (13), Needleman *et al.* (14), the Jadad scale (15) and the Delphi List (16). Criteria were designated for each domain of the internal validity, external validity and statistical methods. Each aspect of the score list was given a rating of '+' for informative description of the item at issue and a study design meeting the quality standard, '−' for an informative description without a study design that met the quality standard and '?' for lacking or insufficient information. When random allocation, defined eligibility criteria, blinding of examiners, balanced experimental groups, identical treatment between groups (except for intervention) and report of follow-up were present, the study was classified as having a low risk of bias. When one of these six criteria was missing, the study was considered to have a moderate potential risk of bias. When two or more of these criteria were missing, the study was considered to have a high potential risk of bias, as proposed by Van der Weijden *et al.* (17).

Data extraction

Data from the papers that met the selection criteria were processed for further analysis. Data were extracted with regard to sugar-free chewing gum in comparison with no gum. For studies that presented an intermediate assessment, the baseline and final evaluations were used for this systematic review. The baseline, end and difference mean values and standard deviation (SD) values were extracted by DES and RSK. Disagreements were resolved by discussion, and if the disagreement persisted, the judgment of a third reviewer (GAW) was decisive.

Data analysis

After a preliminary evaluation of the selected papers, considerable heterogeneity was observed regarding the study designs, characteristics, outcome variables and results. Studies were categorized as *non-brushing* studies (i.e. focusing on plaque parameters) and *brushing* studies (i.e. focusing on plaque and gingivitis parameters). Where appropriate, a meta-analysis was performed, and differences in means (DiffM) were calculated using the Review Manager 5.1 software with the 'fixed effects' model (18). Only a few studies could be included to for this quantitative analysis of the total body of evidence. Therefore, data were also summarized using vote counting and are presented in the descriptive manner (Table 5a,b).

Grading the 'body of evidence'

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) system as proposed by the GRADE working group was used to grade the evidence emerging from this review (19, 20). Two reviewers (RSK and DES) rated the quality of the evidence as well as the strength of the recommendations according to the following aspects: risk of bias of the individual studies; consistency and precision among the study outcomes; directness of the study results; and detection of publication bias. Any disagreement between the two reviewers was resolved after additional discussion.

Results

Search and selection results

The searches resulted in 594 unique papers (for more details, see Fig. 1). The screening of titles and abstracts initially identified 16 full-text articles. In total, six papers were excluded after full-text reading based on the eligibility criteria; see Table 1 for the reasons for exclusion. No additional papers could be retrieved from the reference list. Consequently, 10 papers were identified as eligible for inclusion in this review according to the defined criteria for the study design, participants, intervention and outcome. Of these 10 papers, six *non-brushing* studies and four *brushing* studies were assessed for heterogeneity, quality, data extraction and further analyses.

Assessment of heterogeneity

Considerable heterogeneity was observed in the 10 clinical trials regarding the study design, evaluation period, oral prophylaxis, intervention, regimen, funding source and indices.

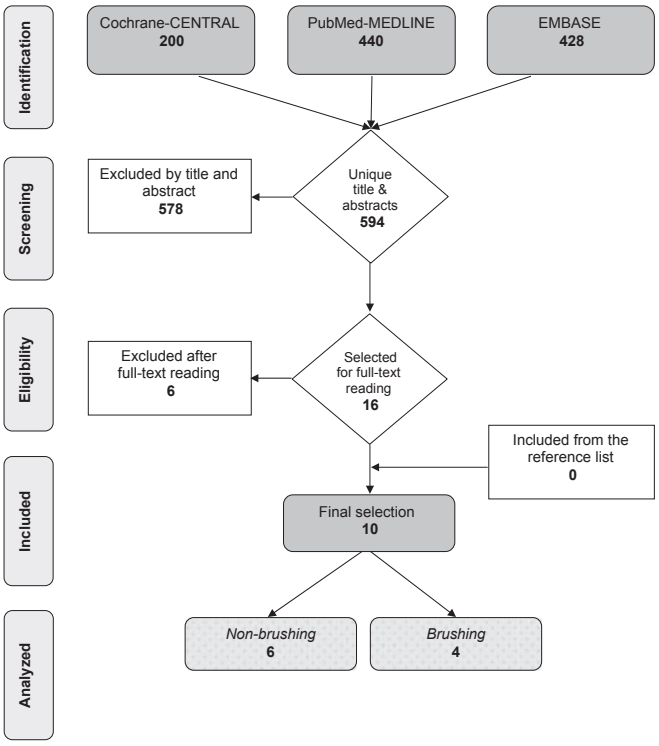

Fig. 1. Search and selection results.

Table 1. **Overview of the studies that were excluded after full-text reading**

Author(s) (year)	Reason for rejection
Kakodkar *et al.* (2010) (44)	No appropriate control group
Kleber *et al.* (2001) (6)	Control groups used breath mints
Simons *et al.* (2001) (36)	Elderly volunteers with (partial) dentures
Reingewirtz *et al.* (1999) (45)	Single use of chewing gum
Yankell & Emling (1997) (39)	Subjects rinsed in addition to the use of chewing gum with CHX
Ainamo *et al.* (1979) (38)	Intervention was sugar-free chewing gum in combination with sucrose gum

CHX, chlorhexidine.

Information regarding the study characteristics, including the study population, is displayed in Table 2.

Study design and subject characteristics. All studies used in this review were single blind. In two studies (IV, VI), blinding was unclear. Nine studies were performed using a cross-over design. The wash-out periods varied from 2 to 9 days. In six experiments (II, III, VII, VIII, IX and X), the subjects received an oral prophylaxis before each test period. In study I, the subjects were asked to brush and floss their teeth to a plaque level of zero. In seven experiments (I, II, IV, V, VI, VII and IX), the trial participants were dental care professionals and/or dental students.

Intervention and regimen. For this review, only sugar-free chewing gum was included as intervention, and chewing gum with specific active/therapeutic ingredients was excluded. Four studies (I, II, III and X) used sorbitol as a sugar substitute in the gum, whereas also four studies (IV, V, VI and X) used xylitol. Study IX used a chewing gum containing both sorbitol and xylitol. In two studies (VII and VIII), it was unclear which sugar substitute was used, although the used chewing gum was clearly sugar-free. Six studies (I, II, III, IV, V and VI) used chewing gum as a monotherapy with no other oral hygiene procedures permitted during the experimental period (*non-brushing* experiments). The other four studies used chewing gum in addition to regular oral hygiene procedures (*brushing* experiments). In three studies (VII, VIII and IX), the study participants used the same toothpaste that had been provided at the start of the experiment. Two studies (VII and X) specifically mentioned that the participants had to abstain from using any other chewing gums or pastilles. The chewing regimens varied per study from chewing one to two gums at the same time, with a varying duration of 10–30 min and a varying frequency of four to six times daily. In study II, the regimen required that the gum be chewed immediately after meals or snacks, resulting in an average of 3.8 gums chewed daily. In two studies (VII and IX), the participants were not allowed to use the gum for 30–60 min before the consumption of any food or drink items; they were also not allowed to eat, smoke or brush their teeth for 2 h before each visit. Study X also mentioned that the subjects not brush or floss on the morning of the examination.

Clinical indices. In this review, different indices and their modifications were used and are presented in Table 4a–c. In study II, the plaque scores were recorded using the Modified Navy Plaque Index (MNPI) (21) along each of four surfaces to assess six Ramfjord teeth (22): 16, 21, 24, 31, 36 and 44. In study III, the plaque levels were assessed using the PI (23) modified by Shaw and Murray (24) on six teeth: 16, 12, 24, 32, 36 and 44. As such, 24 scores in total were obtained for each subject. Study V calculated a mean PI for each individual using four gingival areas of the same six teeth. In study IV, the plaque extent was measured on the buccal surface of the maxillary and mandibular anterior teeth using the planimetric method (25). In studies VII and IX, the visible plaque index (VPI) (26) and gingival bleeding index (GBI) (26) were registered on the teeth in the upper right quadrant, with measurements at six sites on seven teeth, totally 42 sites.

Funding source. Nine studies mentioned funding, support or supplying of products. The Ministry of Education in Finland, the Emil Aaltonen Foundation and the Nutritional Research Foundation of Finnish Sugar Co. Ltd all provided financial aid for studies V and VI. Study IV was partly supported by grants from F. Hoffmann-La Roche and Co., Basle. Fertin Pharma, Cadbury EMEA and Chew Tech were responsible for providing chewing gum and funding for study VII. The Wrigley Company Ltd supplied the chewing gum for two of the studies (I and III). One article (II) included authors who were employed by Wm. Wrigley Jr. Company. Fertin Laboratories provided the chewing gum for study IX, which was also supported by Patentmedelsfonden för Odontologisk

Table 2. **Overview of the included *non-brushing* and *brushing* studies processed for data extraction**

No. Authors (year)	Study design, duration	No. of subjects baseline (end), age in years, gender	Groups	Regimen: use and instruction	Authors' conclusions
I. Hanham & Addy (2001) (46)	RCT Cross-over Single blind 4 days	11 (11) ♀: 10 ♂: 1 Mean age: ? Age range: 22–32	Gum [Sorbitol (Wrigley)] No gum	1 gum, 4 × daily, 30 min Non-brushing	Chewing gum can reduce the plaque accumulation at the sites of predilection for caries but has little or no effect at sites of predilection for gingivitis
II. Hoerman *et al.* (1990) (47)	CCT Cross-over Single blind 5 days	20 (19) ♀: 10 ♂: 10 Mean age: 26 Age range: ?	Gum (Sorbitol) No gum	1 gum, 3.8 × daily, 20 min Non-brushing	Chewing gum caused significantly less plaque accumulation than no chewing
III. Addy *et al.* (1982) (48)	RCT Cross-over Single blind 5 days	10 (?) ♀: 4 ♂: 6 Mean age: ? Age range: 20–22	Gum [Sorbitol (Wrigley)] No gum	1 gum, 5 × daily, 30 min Non-brushing	Chewing gum was capable of removing plaque deposits from the more exposed aspects of tooth surfaces
IV. Plüss (1978) (49)	RCT Cross-over Blinding ? 3 days	18 (?) ♀: 6 ♂: 12 Mean age: 23.5 Age range: ?	Gum (Xylitol) No gum	1 gum, 5 × daily, 15 min Non-brushing	The statistical analysis of the planimetric plaque determinations showed no significant differences between treatments
V. Mouton *et al.* (1975) (50)	RCT Parallel Single blind 3 days	64 (64) ♀: ? ♂: ? Mean age: ? Age range: 19–25	Gum (Xylitol) No gum	1–2 gums, 4 × daily, 10 min Non-brushing	The mean plaque index showed no significant differences between chewing gum and no chewing
VI. Mouton *et al.* (1975) (51)	RCT Cross-over Blinding ? 3 days	20 (?) ♀: 15 ♂: 5 Mean age: ? Age range: 20–25	Gum (Xylitol) No gum	1 gum, 6 × daily, 10 min Non-brushing	The use of a xylitol chewing gum induced a reduction in invertase-like activity in the extracellular phase of plaque
VII. Lingström *et al.* (2005) (35)	RCT Cross-over Single blind 3 months	30 (30) ♀: 19 ♂: 11 Mean age: 53 Age range: ?	Gum (Sugar-free) No gum	1 gum, 5 × daily, 10 min Normal toothbrushing Toothpaste containing 0.32% sodium fluoride (Colgate)	The VPI and GBI revealed statistically significantly lower values after chewing gum compared with no gum
VIII. Barnes *et al.* (2005) (52)	RCT Cross-over Single blind 5 days	18 (18) ♀: 6 ♂: 12 Mean age: ? Age range: 18–65	Gum [Sugar-free (Colgate Dental Gum Advanced Whitening)] No gum	2 gums, 5 × daily, 20 min Brushing twice daily for 1 min (Colgate Winterfresh Gel Dentifrice)	Colgate Dental Gum provided a plaque-control benefit. Chewing gum may serve as an effective oral hygiene device when brushing may not be possible, and chewing gum may serve as an effective adjunct to brushing for enhanced oral health

Table 2. **(continued)**

No. Authors (year)	Study design, duration	No. of subjects baseline (end), age in years, gender	Groups	Regimen: use and instruction	Authors' conclusions
IX. Fure *et al.* (1998) (37)	RCT Cross-over Single blind 3 months	30 (29) ♀: 16 ♂: 13 Mean age: 40 Age range: 22–75	Gum (Sorbitol, xylitol) No gum	1 gum, 5 × daily, 10–20 min Normal toothbrushing Toothpaste containing 0.055% sodium fluoride (ACTA)	The frequent use of a sugar-free chewing gum can be considered to be beneficial from an overall oral health point of view
X. Steinberg *et al.* (1992) (53)	RCT Cross-over Single blind 6 weeks	28 (25) ♀: ? ♂: ? Mean age: ? Age range: ?	Gum (Xylitol) Gum (Sorbitol) No gum	1 gum, 5 × daily, 10 min Normal oral hygiene	Chewing xylitol and sorbitol gums reduced plaque accumulation and gingival inflammation

RCT, randomized controlled clinical trial; CCT, controlled clinical trial; VPI, visible plaque index; GBI, gingival bleeding index; ?, unknown.

Profylaxforskning. The Colgate-Palmolive Company supported study VIII. Study X was supported by a grant from Leaf Inc. of Bannockburn, IL, which also supplied the experimental chewing gums.

Study quality

Quality assessment values, including internal, external and statistical validities, are presented in Table 3. Because of practical reasons in the study design of chewing gum comparing no gum, blinding of subjects was not applicable. On the basis of a summary of the criteria, the estimated potential risk of bias was low for three studies (VII, VIII and X), moderate for three studies (I, V and IX) and high for the four other studies (II, III, IV and VI).

Study outcomes

Information regarding the study outcomes is presented in Tables 4a–c. The outcomes are presented for the *non-brushing* and *brushing* studies.

Changes within groups. Only in a few studies were significant differences clear within the groups. In study IX, the GBI was significantly lower after the testing period compared with baseline values in both groups. In study X, only at the end of the sorbitol gum period was there a statistically significant decrease in the gingival index ($P < 0.05$).

Comparison between groups. Table 5 presents a summary of the descriptive data regarding significant differences between chewing gum groups and control groups (Table 5a for the *non-brushing* studies and Table 5b for the *brushing* studies).

Plaque score. Among the *non-brushing* studies, only one study (III) showed a significant reduction in the plaque score. In three studies (I, II and IV), the intervention groups involving sugar-free gum showed no significant differences compared with the 'no gum' groups. In another two studies (V and VI), the statistical significance between the groups was not clearly indicated by the authors of the papers.

In three of the four *brushing* studies (VII, VIII and X), the four interventions with chewing gum showed a significant reduction in the plaque score when compared with the 'no gum' groups. Study IX found no significant differences in the mean values of VPI between the chewing gum group and the 'no gum' group.

Bleeding tendency and gingival index. Two studies (VII and IX) evaluated the tendency of bleeding upon probing. One study (VII) revealed significantly lower values of the GBI with gum chewing than with no gum ($P < 0.05$). Only one study (X) evaluated the gingival inflammation. After chewing with sorbitol-containing gum, there was a significant decrease in the gingival index ($P < 0.05$) compared with the no gum group. The xylitol gum showed no significant differences.

Meta-analysis. A meta-analysis was performed to compare the effects of chewing gum as a mono-therapy (*non-brushing*) or in addition to regular oral hygiene procedures (*brushing*). A summary is presented in Table 6.

Table 3. **Methodological, validity and quality scores of the included *non-brushing* and *brushing* studies**

Model study	Non-brushing						Brushing			
Quality criteria	I	II	III	IV	V	VI	VII	VIII	IX	X
Internal validity										
Random allocation*	+	–	+	+	+	+	+	+	+	+
Allocation concealment	?	?	?	?	?	?	+	?	?	?
Blinding of examiner*	+	+	+	?	+	?	+	+	+	+
Blinding during statistical analysis	?	?	?	?	+	?	?	?	?	?
Balanced experimental groups*	+	+	+	+	+	+	+	+	+	+
Reported loss to follow-up*	+	+	–	–	+	–	+	+	+	+
No. (%) of drop-outs	0	1 (5%†)	?	?	0	?	0	0	1 (3.3%†)	3 (10.7%†)
Treatment identical, except for intervention*	+	+	+	+	+	+	+	+	+	+
External validity										
Representative population group	+	+	+	+	+	+	–	+	–	+
Eligibility criteria defined*	–	–	–	–	–	–	+	+	–	+
Statistical validity										
Sample size calculation and power	?	?	?	?	?	?	?	?	?	?
N sufficient for ADA guideline	–	+	–	+	+	+	+	+	+	+
Point estimates	+	+	+	–	+	+	+	+	+	+
Measures of variability presented for the primary outcome	+	–	+	–	+	+	+	+	+	+
Per protocol analysis	+	+	?	?	+	?	–	+	+	+
Include an intention-to-treat analysis	+	–	?	?	+	?	+	+	–	–
Authors' estimated risk of bias	***Mod***	***High***	***High***	***High***	***Mod***	***High***	***Low***	***Low***	***Mod***	***Low***

?, not specified/unclear; +, yes; –, no.
**Reporting criteria for estimating the potential risk of bias.
†Calculated by the authors.

Two meta-analyses were performed for *non-brushing* studies using different indices that evaluated the plaque scores at the end of the trial. One meta-analysis (27) was based on studies I and VI and did not identify statistically significant differences, with a DiffM of 0.03 ($P = 0.75$). The other meta-analysis for the *non-brushing* studies was performed for the combined indices of Silness and Löe (23) and Löe (28), based on studies III and V. This meta-analysis also showed no significant differences ($P = 0.29$).

In the *brushing* studies, with respect to the PI, two meta-analyses for two different indices (26, 27) were performed based on four experiments (VIII, X, IX and VII). The analysis of the Quigley & Hein data (27) indicated a significant difference in favour of chewing gum, with a DiffM of −0.24 and a confidence interval (CI) of [−0.41; −0.08] ($P = 0.004$). The analysis of the Ainamo & Bay data (26) had a DiffM of −4.75% and a CI of [−15.88; 6.39], which was not statistically significant ($P = 0.40$). The test for heterogeneity showed $P = 0.54$ and $I^2 = 0\%$ for the Quigley & Hein analysis. The heterogeneity for the analysis of Ainamo & Bay was $P = 0.04$ and $I^2 = 76\%$.

The meta-analysis of bleeding index (BI) (26), which evaluated two studies (VII and IX), did not show a statistically significant difference, with a DiffM of −1.17 ($P = 0.57$). A meta-analysis for GI was not possible because only one available study (X) addressed that index.

Grading the 'body of evidence'

Table 7 shows a summary of the various aspects that were used to rate the quality of the evidence and the strength of the recommendations according to GRADE (19, 20). Because the data were generally inconsistent with a moderate estimated risk of bias, the precision was very low to moderate (or undeterminable). The study results were generalizable, although the strength of the recommendation to use chewing gum to reduce plaque was considered to be 'weak'.

Discussion

By virtue of its high level of evidence, a systematic review is useful to collect information that provides a solid basis for clinical decision-making (29). A systemic review is a systematic assessment of the available literature for the effects of health care interventions, and it is intended to help professionals and patients in choosing appropriate regimens. This systematic review investigated whether sugar-free chewing gum provided a benefit with respect to plaque scores and parameters of gingival inflammation.

Chewing gum is a well-accepted, enjoyable and frequent activity for adults and children, and it is also purported to reduce the risk of dental caries. There is consistent evidence to support the use of sugar-free chewing gum as a part of normal oral hygiene (1, 3, 4, 30). The American Academy of Pediatric Dentistry has endorsed the use of xylitol-containing products for caries prevention. The Dutch organization Ivory Cross (Ivoren Kruis), which promotes oral and dental health, has also provided an endorsement for the use of xylitol-containing gum. Furthermore, the American Dental Association (ADA) recommends sugar-free gum. Several sugar-free gum brands carry the ADA seal of approval on their packaging.

Table 4. **Mean (SD) scores for the different intervention groups are presented separately for *non-brushing* and *brushing* studies, with different indices and their modification**

Model	No.	Index	Intervention groups	Mean (SD) Baseline	End	Difference	Significant
(a) Plaque score							
Non-brushing	I.	Quigley & Hein (1962) (27)	Gum (sorbitol)	0*	2.30 (0.26)	+2.30*	?
		Turesky *et al.* (1970) (54)	No gum	0*	2.39 (0.26)	+2.39*	?
	VI.	Quigley & Hein (1962) (27)	Gum (xylitol)	?	3.44 (0.18*)	?	?
		Bay *et al.* (1967) (55)	No gum	?	3.31* (0.21*)	?	?
	III.	Silness & Loë (1964) (23)	Gum (sorbitol)	0*	1.32* (0.53*)	+1.32*	?
		Shaw & Murray (1977) (24)	No gum	0*	2.61* (0.65*)	+2.61*	?
	V.	Löe (1967) (28)	Gum (xylitol)	?	1.43 (0.25)	?	?
			No gum	?	1.49 (0.24)	?	?
	II.	Navy plaque index (1972) (21)	Gum (sorbitol)	1.9	3.3	+1.4*	?
		Fischman *et al.* (1987) (56)	No gum	2.0	3.6	+1.6*	?
	IV.	Planimetric method	Gum (xylitol)	?	15.02	?	?
		Plüss *et al.* (1975) (25)	No gum	?	15.78	?	?
Brushing	VIII.	Quigley & Hein (1962) (27)	Gum (Colgate	0*	1.38 (0.50)	+1.38*	?
		Turesky *et al.* (1970) (54)	Dental Gum)	0*	1.81 (0.65)	+1.81*	?
			No gum				
	X.	Quigley & Hein (1962) (27)	Gum (xylitol)	0*	1.64 (0.37)	+1.64*	?
		Turesky *et al.* (1970) (54)	Gum (sorbitol)	0*	1.70 (0.43)	+1.70*	?
			No gum	0*	1.87 (0.38)	+1.87*	?
	VII.	Ainamo & Bay (1975) (26)	Gum (sugar-free)	$\bar{x}$ 35.8%	26.3% (12.0%)	−9.5%*	No
			No gum	(14.0%)	37.2% (15.6%)	+1.4%*	No
	IX.	Ainamo & Bay (1975) (26)	Gum (sorbitol	$\bar{x}$ 16.9%	12.6% (12.4%)	−4.3%*	No
			+ xylitol)	(14.4%)	12.1% (9.0%)	−4.8%*	No
			No gum				
(b) Bleeding score							
Brushing	VII.	Ainamo & Bay (1975) (26)	Gum (sugar-free)	$\bar{x}$ 16.1%	11.0% (9.8%)	−5.1%*	No
			No gum	(11.0%)	15.5% (11.5%)	−0.6%*	No
	IX.	Ainamo & Bay (1975) (26)	Gum (sorbitol +	$\bar{x}$ 7.2%	4.1% (5.2%)	−3.1%*	Yes
			xylitol)	(7.0%)	4.0% (4.9%)	−3.2%*	Yes
			No gum				
(c) Gingival index							
Brushing	X.	Löe & Silness (1963) (57)	Gum (xylitol)	$\bar{x}$ 2.00	1.90 (0.33)	−0.10*	No
			Gum (sorbitol)	(0.43)	1.82 (0.42)	−0.18*	Yes
			No gum		2.00 (0.39)	0*	No

?, unknown.
*Calculated by the authors of this review based on the presented data in the selected papers.

Qualitative analysis

The methods used to synthesize and summarize empirical results can be differentiated into narrative reviews, vote counting and meta-analysis. If only a few studies can be used for a meta-analysis (i.e. because of limited reporting of end-point data), all available information cannot be effectively utilized. For this reason, Light and Smith (31) developed the so-called vote-counting method, which distinguishes significant positive, significant negative and non-significant results. Vote-counting procedures probably constitute the most common quantitative technique used in the reviewing of research. Such a technique is appealing because it is easy to use, requires a minimal amount of statistical data from each study to be integrated and permits the merging of analyses from different studies.

To generate conclusions about the 'true direction of the relationship', investigators often use the 33% rule (i.e. a positive/negative effect is identified if the relative frequency of the significant/negative results exceeds 33%). However, such rules do not include differences between methods applied within the studies, and they do not account for differences in the sample size or the actual strengths of the values. The problem with vote counting is that each study and each vote is treated as equal. Comparisons with a positive direction fail to provide an estimate of the effect size of an intervention (i.e. giving equal weight to comparisons that show a 1% change or a 50% change) and ignore the precision of the estimates from the primary comparisons (i.e. giving equal weight regardless of the number of participants). The present review found that four of five *brushing* comparisons showed a significant beneficial effect of gum with regard to the plaque scores (Table 5B). The sample size of these studies was small, ranging from 18 to 30 subjects with durations of 5 days–3 months. The calculated effect size was a 9–24% reduction in plaque scores compared to the 'no gum' group (Table 4).

Table 5. **A summary of the descriptive data on whether there are statistically significant differences between the use of chewing gum and no use of chewing gum**

Study model	No.	Intervention	No. of gums Frequency and Duration of use	Plaque score	Bleeding score	Gingival index	Comparison
(a) Non-brushing design studies							
Non-brushing	I.	Gum (sorbitol)	1 gum, 4 × daily, 30 min	○			No gum
	II.	Gum (sorbitol)	1 gum, 3.8 × daily, 20 min	○			No gum
	III.	Gum (sorbitol)	1 gum, 5 × daily, 30 min	+			No gum
	IV.	Gum (xylitol)	1 gum, 5 × daily, 15 min	○			No gum
	V.	Gum (xylitol)	1–2 gums, 4 × daily, 10 min	?			No gum
	VI.	Gum (xylitol)	1 gum, 6 × daily, 10 min	?			No gum
(b) Brushing design studies							
Brushing	VII.	Gum (sugar-free)	1 gum, 5 × daily, 10 min	+	+	□	No gum
	VIII.	Gum (Colgate Dental Gum Advanced Whitening)	2 gums, 5 × daily, 20 min	+	□	□	No gum
	IX.	Gum (Sorbitol, xylitol)	1 gum, 5 × daily, 10–20 min	○	○	□	No gum
	X.	Gum (xylitol)	1 gum, 5 × daily, 10 min	+	□	○	No gum
		Gum (sorbitol)	1 gum, 5 × daily, 10 min	+	□	+	No gum

+, intervention was significantly more effective; ○, no significant difference; ?, unknown/unclear; □, no data available.

Table 6. **Meta-analysis comparing the use of chewing gum to no use of chewing gum**

				Test for overall effect		Test for heterogeneity	
Model	Index	Studies	DiffM (random)	95% CI	*P*-value	*P*-value	I^2 (%)
Non-brushing	PI Quigley & Hein (1962) (27)	I. VI.	0.03	[−0.18; 0.25]	0.75	0.10	62
	PI Silness & Loë (1964)(23)/(1967) (28)	III. V.	−0.65	[−1.85; 0.56]	0.29	< 0.00001	95
Brushing	PI Quigley & Hein (1962) (27)	VIII. X.	−0.24	[−0.41; −0.08]	0.004	0.54	0
	VPI Ainamo & Bay (1975) (26)	VII. IX.	−4.75%	[−15.88; 6.39]	0.40	0.04	76
	BI Ainamo & Bay (1975) (26)	VII. IX.	−1.17%	[−5.20; 2.86]	0.57	0.23	31

DiffM, difference in means; CI, confidence Interval; PI, plaque index; VPI, visible plaque index; BI, bleeding index.

Table 7. **GRADE evidence profile for the impact of the use of chewing gum in comparison with no gum on plaque and gingivitis scores**

Follow-up	Non-brushing	Brushing		
Outcome	Plaque score	Plaque score	Bleeding score	Gingival index
Risk of bias	Moderate–high	Low–moderate	Low–moderate	Low
Consistency	Inconsistent	Fairly consistent	Inconsistent	Inconsistent
Directness	Not generalizable	Generalizable	Generalizable	Generalizable
Precision	Moderate	Very low	Moderate	Undeterminable
Publication bias	Possible	Possible	Possible	Possible
Strength of recommendation	***Very weak***	***Weak***	***Weak***	***Very Weak***

Because the sample sizes of the studies are not taken into account in vote counting, this procedure is biased towards studies with small sample sizes, which are given the same weight as studies with large sample sizes (32). The power of the conventional vote-counting procedure tends to approach zero as the number of studies with medium or small effect sizes increases. In fact, small, moderate and even large effect sizes may yield a non-significant *P*-value because of inade-

quate statistical power, especially when the sample size is too small. Therefore, the absence of a statistically significant effect is not evidence of the absence of an effect. The lack of statistical significance could also be the result of a low statistical power. This limitation, however, was not applicable to this review because four of the five *brushing* comparisons showed a significant effect, which indicates that the studies had sufficient power; as such, inadequate power was not a limiting issue in our review. Moreover, three studies (VII, VIII and X) had a low estimated risk of bias (Table 3).

It is remarkable that three *non-brushing* studies indicated that the chewing of sugar-free gum did not provide a significant clinical benefit in the absence of toothbrushing (Table 5a). As suggested above, however, this finding could be a result of insufficient statistical power, as only 11–20 subjects were included in these studies. For the two Mouton studies (V and VI), the outcome differences between the groups were unclear.

Quantitative meta-analysis

In the absence of brushing, the scientific evidence for sugar-free chewing gum is insufficient to support a proposed significant clinical benefit, as it did not permit a quantitative meta-analysis. Two studies of sugar-free chewing gum as an adjunct to brushing were used for a meta-analysis of the Quigley and Hein PI (27), which showed a significant reduction in plaque scores. However, this significant difference was small, with a difference in means (DiffM) of −0.24 on a 5-point scale based on the Quigley and Hein PI (27). Other meta-analyses evaluated plaque score and bleeding tendency using the Ainamo and Bay indices (26) and showed no significant differences. The meta-analysis that included study IX did not observe any effects for PI or BI. Therefore, the outcome of the meta-analysis was not surprising, with one included study showing a significant effect and another study with a similar sample size not showing any effects. Combining the data of the two studies (VII and IX) showing the effects in opposite directions, may dissipate any overall effect in the summary statistics.

Regimen

The chewing regimens of the included studies involved chewing of one to two gums, for 10–30 minutes with a frequency of 3.8 to six times daily. Three studies had excessive amounts of chewing time of 100, 120 and 150 min. In study III, the participants used one chewing gum five times a day for 30 min (which means that they chewed gum for 150 min each day). In another study (I), the participants chewed four times daily for 30 min each (for a total of 120 min). In study VIII, participants chewed five times daily for 20 min each (for 100 min total each day). Chewing times of longer than 100 min may not represent a 'real-life' situation. Moreover, prolonged gum chewing can result in pain in the facial muscles. The extensive use of chewing gum containing sugar substitutes may have adverse effects, as well. Relatively large amounts of xylitol or sorbitol can be consumed without untoward side effects, although when ingested in abundant quantities, they can act as a laxative and cause flatulence and diarrhea (4, 33, 34). The present review found that when one gum was chewed for 10 min five times daily, a positive effect on the reduction of plaque score occurred in the majority of *brushing* comparisons (VII, X). As a recommendation to our patients, such a regimen may therefore be adequate to reduce intra-oral plaque.

Ingredients

In particular, this systematic review focused on the use of sugar-free chewing gum compared with no gum and excluded interventions involving sugar-free chewing gum with additional active/therapeutic ingredients. Medicated gums containing, for example, vitamin C (35), chlorhexidine acetate (CHX) (36) or urea (37) were excluded because these ingredients may have an impact on the presence of plaque or gingival inflammation. Furthermore, studies were excluded if, aside from the chewing gum, the interventions were not identical between the test and control groups. For instance, the control group used breath mints in some studies (6, 7). In another study, the participants also used a sucrose-containing gum (38). Yet another study included a CHX rinse (39). By selecting only those studies that included sugar-free chewing gum, we may have introduced a limitation. Active ingredients other than sugar substitutes such as xylitol and sorbitol might provide more favourable outcomes for plaque and gingivitis scores.

Sugar substitutes

The most common polyols in sugar-free chewing gum are sorbitol and xylitol (4), which were also the sucrose substitutes in the studies that were retrieved for this review. Xylitol over other polyol sugars has been suggested to reduce caries incidence; however, the clinical evidence is not unequivocal. Some reviews do not support this position (40), while others point to superior efficacy for xylitol. Two systematic reviews (3, 30) and two narrative reviews (1, 4) published in recent years have stated that the regular use of xylitol or sugar-free chewing gum could play a role in the prevention or reduction of dental caries. The reason for this is the inability of bacteria to metabolize polyols into acids. The efficacious dose range has been determined to be 6–10 g day^{-1}, based on data showing the suppression of salivary *Streptococcus mutans* counts (41). To deliver this amount of xylitol in a day requires consumption of at least five gums sweetened with xylitol as the only polyol sweetener, assuming a 2 g serving size with 60% xylitol. All included papers using xylitol as sweetener, used at least five gums per day. Although an antimicrobial effect of xylitol cannot be excluded. It has alternatively been hypothesized that the observed caries reduction is the result of the stimulation of saliva production during the chewing process. This plays a role in accelerating the clearance process in the oral cavity (37, 40).

Sorbitol is the standard sweetener in several sugar-free chewing gums and in over-the-counter medicines. Sorbitol is 60% as sweet as sucrose and is much less costly than xylitol. Sorbitol is, however, less effective than xylitol in controlling caries, but its lower cost makes it appealing to food manufacturers (4). Because sorbitol is a low-cariogenic sweetener rather than a non-cariogenic sweetener, dentists should advise their patients who chew sorbitol-sweetened gum to do so no more than three times per day (4).

Subjects

In accordance with the American Dental Association (ADA) guideline for sugar-free chewing gums (2010) (10), a sample size of at least 15 subjects was deemed to be necessary for the study objectives. In this review, two studies (I and III) did not meet that criterion. These studies were *non-brushing* studies that had only 10 and 11 participants. This limited number of participants may have negatively impacted the outcome and power of the *non-brushing* studies. Studies were excluded for this review when they included subjects who were ≤ 18 years old. This age restriction was also based on the ADA guideline. Subjects with orthodontic appliances or elderly patients with (partial) dentures were also excluded.

In seven included studies (I, II, IV, V, VI, VII and IX), the participants were dental professionals or dental students. The periodontal condition and the oral cleaning habits of these specific participants are likely to be better than those of the more general population. The participants who were dental professionals were also possibly more aware and motivated to follow the experimental protocol (42). For the *non-brushing* studies, the inclusion of dental professionals or dental students was not deemed to be a critical item. However, the *non-brushing* aspect of these studies was considered to have a negative impact on their generalizability.

Limitations

- This may be the restriction to published work in the English language. It is conceivable that authors are more likely to report in an international, English-language journal if results are positive, whereas negative findings are published in a local journal. While the potential impact of studies published in languages other than English in a meta-analysis may be minimal, it is difficult to predict in which cases this exclusion may bias a systematic review (43).
- Another limitation may be the use of published research papers only. The authors of this review did not have the resources to obtain data that are kept on file by the various chewing gum manufacturers.

Conclusion

In this systematic review, the clinical effects of chewing sugar-free gum on plaque and the parameters of gingival inflammation were investigated.

Within the limitations of this systematic review, it may be concluded that the use of sugar-free chewing gum as an adjunct to toothbrushing provides a small but significant reduction in plaque scores. Chewing sugar-free gum showed no significant effect on gingivitis scores. In the absence of brushing also no scientific evidence for a beneficial effect of sugar-free chewing gum could be established, possibly because of inadequate power of the study designs.

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Directions for further research

Based on observations in various chewing gum studies that are performed over many years, the suspicion is there that sugar-free chewing gum may provide beneficial effects with respect to both plaque and gingivitis scores (see Table 5B). However this systematic review indicates that properly designed studies with adequate numbers of subjects are definitely needed to demonstrate these effects. More specifically, the lack of evidence and study designs with inadequate power were observed for the *non-brushing* studies. Improvements in these areas could be a direction for further research. Furthermore, although plaque scores have received much attention in the *brushing* studies, the parameters of gingival inflammation have not received much interest in the past. Focusing on oral health improvements could therefore also be a direction for the future.

Conflict of interest

The authors declare that they have no conflicts of interest. The authors independently designed the study project. The study was performed with a commission from ACTA Dental Research BV. ACTA Research BV received financial support from Wm. Wrigley Jr. Company for the role of the Department of Periodontology of ACTA in this project.

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