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EFECTIVIDAD ANTIBACTERIANA Y ACCIÓN PERIODONTAL DE LAS GOMAS DE MASCAR LIBRES DE AZÚCARES EN PACIENTES CON TRATAMIENTO DE ORTODONCIA FIJA: REVISIÓN SISTEMÁTICA

INFORME DE INVESTIGACIÓN PREVIO A LA OBTENCIÓN DEL TÍTULO DE ESPECIALISTA EN ORTODONCIA

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Agradecimiento

A Dios, por darme la vida, la fortaleza y la sabiduría para culminar este camino.

A mis padres, por su amor infinito, por enseñarme con su ejemplo el valor del esfuerzo, la constancia y la humildad, y por ser mi mayor inspiración en cada paso de mi vida académica y personal.

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Dedicatoria

"El amor de los padres hacia los hijos es el único amor eterno."
— William Shakespeare

A mis amados padres, pilares de mi vida y fuente inagotable de amor.
Por cada sacrificio silencioso, por cada palabra de aliento y por cada gesto de ternura que me han sostenido en los momentos más difíciles.
Este logro no me pertenece solo a mí, sino también a ustedes, que con su ejemplo de fortaleza, esfuerzo y entrega me enseñaron a luchar por mis sueños.
Con gratitud infinita y con todo mi corazón, dedico estas páginas a quienes me dieron la vida y me enseñaron a vivirla con dignidad y esperanza.

Resumen

Objetivo: En pacientes sometidos a tratamiento ortodóntico fijo, la limpieza mecánica suele verse comprometida debido al acceso limitado a todas las superficies orales.

Propósito: Esta revisión sistemática tuvo como objetivo evaluar la efectividad antimicrobiana y los beneficios periodontales de los chicles sin azúcar en pacientes con aparatología ortodóntica fija, basándose en ensayos clínicos aleatorizados.

Materiales y Métodos: Se realizó una búsqueda exhaustiva en bases de datos electrónicas para identificar estudios publicados hasta 2024, siguiendo la estrategia PICO. La revisión se llevó a cabo conforme a la guía PRISMA y fue registrada en PROSPERO (CRD42023444472). Se empleó la herramienta Cochrane RoB 2 para evaluar el riesgo de sesgo y el sistema GRADE para determinar la certeza de la evidencia.

Resultados: Se incluyeron cinco ensayos clínicos aleatorizados. Dos estudios reportaron reducciones significativas de *Streptococcus mutans* en saliva (−17% a −33%) y en placa dental (−20% a −29%) ($p<0,05$), siendo el chicle de xilitol y la mezcla xilitol–sorbitol los que mostraron mayor efecto tras un mes de consumo (GRADE: alto). Dos estudios demostraron disminuciones notables en el índice de placa (−43% a −47%, $p<0,05$) con chicle de xilitol tras un mes; también se observaron reducciones con chicles de aceites esenciales (10 días) y de sorbitol (tres meses) (GRADE: bajo). Los chicles de clorhexidina, sorbitol y aceites esenciales redujeron eficazmente el sangrado gingival, y el chicle de xilitol aumentó el pH salival. Más del 50% de los estudios presentaron alto riesgo de sesgo, mientras que menos del 25% fueron considerados de bajo riesgo (GRADE: bajo).

Conclusiones: Los chicles sin azúcar demostraron efectos beneficiosos en la salud oral de pacientes con ortodoncia fija. La evidencia disponible sugiere que el xilitol, solo o combinado con sorbitol, reduce eficazmente los niveles de *S. mutans* en saliva. No obstante, la heterogeneidad y las limitaciones metodológicas restringen la generalización de los resultados. Se requieren ensayos clínicos más amplios y de mayor duración para confirmar su eficacia y fortalecer las recomendaciones clínicas.

Abstract

Aim: In patients with fixed orthodontic appliances, the effectiveness of mechanical cleaning is compromised due to difficulties in accessing all áreas of the mouth.

Purpose: Aimed to evaluate the antimicrobial effectiveness and periodontal actions of sugar-free chewing gums in patients with fixed orthodontics through a systematic review of randomized clinical trials.

Materials and Methods: A bibliographic search was conducted in digital databases for articles published up to 2024 in accordance with the PICO question. This review followed the PRISMA methodology and was registered in PROSPERO (CRD42023444472), while the Cochrane RoB 2 tool used to assess the risk of bias and GRADE employed to evaluate the certainty of evidence for each outcome.

Results: Five studies were included. A significant reduction *Streptococcus mutans* in saliva was observed in two studies (−17%-33% saliva, −20%-29% dental plaque, $p<0.05$), with xylitol gum and it's mixture with sorbitol exerting the best effect after one month of consumption (GRADE high). An effective decrease in the plaque index was observed in two studies of xylitol gum (−43% −47%, $p<0.05$) after one month of consumption, as well as studies of essential oil gum (10 days) and sorbitol gum (three months) (GRADE low). Chlorhexidine, sorbitol, and essential oil gums effectively reduce gingival bleeding, and xylitol gum increases the salivary pH, more than 50% presented a high risk of bias, and less than 25% were at low risk of bias (GRADE low).

Conclusion: The different types of chewing gum significantly improved the oral health of patients with fixed orthodontics, the quality of evidence suggests that chewing gums could decrease the level of SM in saliva (4:1 xylitol and sorbitol mix or xylitol). However, the heterogeneity of the studies limits the generalization to other outcomes which highlights the need for larger and longer clinical trials to confirm their efficacy.

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1. INTRODUCTION

Additionally, fixed orthodontic appliances not only increases dental plaque but also induces changes in the oral environment, increasing the levels of *Streptococcus* ions and just in few cases periodontitis.[8] Studies have reported a progressive increase in the number of SM colony-forming units (CFUs/mL) for up to six months of fixed orthodontic therapy. Compared with removable appliances, fixed orthodontics increase the probability of developing dental caries fivefold due to high SM concentrations (>105 CFUs/mL). The plaque index also progressively increases, with statistically significant differences observed at three months and six months of orthodontic therapy.[9] Additionally, studies compare before and during orthodontic treatment with a 60% increase in the dental plaque index and a 37% deterioration in the gingival index after seven months of fixed orthodontic therapy applied in adolescents and adults.[10]

Antiseptic mouthwashes containing cationic biocides such as chlorhexidine digluconate (CHX), cetylpyridinium chloride (CPC)[5] or antiseptic rinses containing essential oils[11] have been used to prevent plaque accumulation and gingivitis development. However, prolonged and frequent use can promote resistance to these antiseptics, as plaque colonizing microorganisms adapt phenotypically to CHX or CPC.[5] Therefore, the chewing gum remains in the mouth longer than mouth rinses do.[5,12] Chewing gum stimulates salivary flow, neutralizes and increases the pH, and serves as a medium for delivering therapeutic agents.[13,14] Children and adolescents spend more time chewing gum than brushing their teeth during oral hygiene, which may help ameliorate gingival or periodontal inflammation,[15,16] therefore, sugar- free chewing gum can be a valuable complement to oral hygiene within public health and should be promoted as a method of preventing dental caries that centre around the stimulation of salivary flow. However, it is not a replacement for traditional oral hygiene procedures, such as toothbrushing, toothpicks, floss wire and mouthrinses.[14]

Currently, essential oils (EOs) are being used for have long been known to have anti-inflammatory, immunodomo- dulatory, bronchodilatoy and antiviral. Moreover, EOs contain multiple active phytochemicals that can act synergistically on multiple stages of viral replication, owing to their lipophilic nature are advocated to penetrate viral membranes easily leading to membrane disruption.[17] A chewing gum containing natural

antiseptic ingredients demonstrated a significant potential to reduce SARS-CoV-2 viral load in exhalative air and in this way, reduce further spread and infection risk.[18]

The global increase in sugar consumption has led to the development of chewing gums containing sugar substitutes, including polyols or nonfermentable sugars, the most commonly used of which are nutritive sweeteners such as sorbitol, maltitol, and xylitol.[19–23] Xylitol-containing gums are not fermented by cariogenic bacteria in plaques and, therefore, do not lower plaque pH, preventing enamel demineralization and bacterial proliferation. Xylitol is absorbed and accumulates intracellularly in SM, competing with sucrose for a transporter in the cell wall and its intracellular metabolic processes. SM expends energy to break down the accumulated xylitol without producing energy in return.[24] The presence of xylitol at 100% concentration in chewing gums is estimated to increase salivary pH levels compared with those in chewing gums containing 22% xylitol; however, in both cases, the bacterial load is reduced after 30 days of consumption,[24,25] and even the consumption of low doses of 2.5 g of xylitol chewing gum per year provide an effective means of preventing dental caries in at-risk individuals.[26]

Currently, other compounds are being introduced into chewing gums[27] for the prevention of oral diseases, including mastic gum;[1,28] polyols such as xylitol,[3,20,29–39] sorbitol,[3,35,40,41] sorbitol + xylitol;[3] essential oils;[5] other chemical compounds, such as ethylenediaminetetraacetic acid (EDTA),[42] chhorexidine,[40] and urea;[43] natural compounds such as casein phosphopeptide amorphous calcium phosphate CPP-ACP),[15] magnolia bark extract (MBE),[14] and propolis;[44] or a combination of both chemical and natural compounds, such as MicroRepair®BIOMA gums (biomimetic hydroxyapatite microcrystals combined with probiotics).[45]

Therefore, a regimen based on sugar free chewing gums may be well suited for young patients undergoing orthodontic therapy. It may produce a pumping effect that allows the active component of the gum to effectively penetrate the narrow spaces between the teeth and the orthodontic appliance. This systematic review addresses the following research questions: (1) Can the consumption of sugar-free chewing gums derived from alcohol or plant-base extracts reduce SM salivary levels, improve periodontal health, and increase saliva flow and pH levels? (2) Are there differences in the effects of chewing gums made from different alcohols, blends, and plant derivatives?

In addition, previous studies have used different ways of monitoring chewing gum consumption, such as dosage, chewing time, different agents in patients without orthodontic treatment, hence the need for further research, therefore, the objective of this study was to evaluate the antimicrobial effectiveness and periodontal actions of sugar-free chewing gums in patients with fixed orthodontics through a systematic review of randomized clinical trials.

2. MATERIALS AND METHODS

2.1 RESEARCH QUESTION

The research question for this systematic review was formulated using the PICO framework (patients, intervention, control, outcome): patients with fixed orthodontic treatment (P), using sugar-free chewing gums derived from alcohol or plant-base extracts (I), compared to a control such as a placebo or sugared gums (C), and an analysis of antimicrobial effectiveness against sm at the salivary level and the decrease in gingival inflammation assessed at the level of dental plaque, gingival index and bleeding, saliva flow, and salivary ph level (O).

2.2 SEARCH STRATEGY

The PRISMA (preferred reporting items for systematic reviews and meta-analyses) 2020 statement was used as a guide when conducting this systematic review. The review was registered in PROSPERO (crd42023444472) before data collection began.

2.3 STUDY SELECTION

The systematic review analysed five databases: PubMed, the Cochrane Library, Scopus, Ovid, Web of Science, Lilacs, and a grey literature database (ClinicalTrials). Additionally, a manual search of the reference lists of previous systematic reviews on the topic was conducted. The search was performed from December 29 to 30, 2024. The search terms used are shown in Table 1. The search was not limited exclusively to studies on chewing gums.

Database	Search Terms
PubMed	((((((Orthodontic appliances) AND (Fixed)) OR (Adult)) OR (Child)[MeSH Terms]) AND (((((((Chewing Gum) AND (Sugar Alcohols)) OR (Asteraceae)) OR (Magnoliaceae)) OR (Magnolia)) OR (Hexoses)) OR (Gum Arabic)) OR (Mastic Resin)[MeSH Terms])) AND ((Chewing Gum) OR (Sugar)[MeSH Terms])) AND ((((((Biofilms) OR (Dental Plaque)) OR (*Streptococcus mutans*)) OR (Periodontal Index)) OR (Dental Plaque Index)) OR (Saliva)[MeSH Terms])
Cochrane Library	((orthodontic appliance) AND (fixed) OR (adult) OR (child) AND (chewing gum) AND (sugar-alcohols) OR (Asteraceae) OR (Magnoliaceae) OR (gum arabic) OR (chewing gum) OR (Magnolia) OR (hexose) OR (mastic gum) OR (gum arabic) AND (chewing-gum) OR (sugar alcohol) AND (biofilm) OR (dental plaque) AND (*Streptococcus mutans*) AND (periodontal index) AND (saliva)):kw (word variations were searched)
Scopus	((orthodontic AND appliance) AND (fixed) OR (adult) OR (child) AND (chewing AND gum) AND (sugar-alcohols) OR (Asteraceae) OR (Magnoliaceae) OR (gum AND arabic) OR (chewing AND gum) OR (magnolia) OR (hexose) OR (mastic AND gum) OR (gum AND arabic) AND (chewing-gum) OR (sugar AND alcohol) AND (biofilm) OR (dental AND plaque) AND (Streptococcus AND mutans) AND (periodontal AND index) AND (saliva)) AND (LIMIT-TO (DOCTYPE, “ar”))
Ovid	(((((((((orthodontic appliance and fixed and adult) or child) and chewing gum and sugar-alcohols) or Asteraceae or Magnoliaceae or gum arabic or chewing gum or Magnolia or hexose or mastic gum or gum arabic) and chewing-gum) or sugar alcohol) and biofilm) or dental plaque) and *Streptococcus mutans* and periodontal index and saliva)
Web of Science	((((((((((((((((ALL=(orthodontic appliance)) AND ALL=(fixed)) AND ALL=(adult)) OR ALL=(child)) AND ALL=()) AND ALL= (sugar-alcohols)) OR ALL=(Asteraceae)) OR ALL=(Magnoliaceae)) OR ALL=(gum arabic)) OR ALL=(Magnolia)) OR ALL= (hexose)) OR ALL=(mastic gum)) OR ALL=(biofilm)) OR ALL=(dental plaque)) AND ALL=(*Streptococcus mutans*)) AND ALL= (periodontal index)) AND ALL=(saliva) Lilacs: (orthodontic appliance) AND (fixed) AND (adult) OR (Child) AND (chewing gum) AND (biofilm) OR (dental plaque)

3 INCLUSION AND EXCLUSION CRITERIA

Prospective randomized controlled trials (RCTs) describing the effects of sugar-free chewing gums derived from alcohol or plant-based extracts on salivary SM levels, clinical indices at the dental plaque level, gingival bleeding, saliva flow, and salivary pH levels in patients treated with fixed orthodontics were included. The studies compared baseline values with postintervention treatment results. The comparison involved chewing gum with sugar or no product. Additionally, studies had to report the daily dose and method of chewing gum consumption.

Exclusion criteria were evaluated by analysing the title and abstract of systematic reviews and included in vitro studies; case reports; animal studies; studies involving participants without orthodontic treatment or with removable appliances; studies involving disabled subjects (limitation of oral hygiene and failure to chew gum); and research unrelated to oral health, abstracts, commentaries, or study protocols. Studies using alcohol-based vehicles such as candies, tablets, lozenges, mouth rinses or sprays, toothpastes, toothbrushes, pacifiers, and milk, as well as studies that did not report antimicrobial or periodontal effects, studies without a control group, and studies published in languages other than English, were excluded.

4 STUDY SELECTION AND DATA EXTRACTION

Study selection was conducted by two independent reviewers (MLI and MLV) who evaluated the titles and abstracts of articles identified in the search using the Rayyan program.[46] The full texts of the selected studies were then analysed according to predefined inclusion and exclusion criteria. The researchers calibrated their judgments during the evaluation process using two similar systematic reviews. In cases of disagreement regarding study eligibility, the final decision was made by a third reviewer (KCL), who acted as an arbitrator. Disagreements were resolved through consensus, and if they persisted, a modified Delphi technique was used to reach a unified decision.

The following data were collected: (i) author, year of publication, study design, study location, and funding; (ii) population characteristics, such as the number and age of participants and participant conditions; (iii) dose, duration, indication of gum consumption, and types of chewing gums; and (iv) antimicrobial effectiveness against SM in dental plaque and saliva, dental plaque level, gingival bleeding, saliva flow, and salivary pH level evaluated in dental plaque. No study investigated pH in saliva. All values, including means and standard

deviations, were extracted from the selected publications when possible. The authors were contacted by Email in case of doubts or missing data.

5 METHODOLOGICAL QUALITY ASSESSMENT AND RISK OF BIAS

The risk of bias of the included studies was assessed using the Cochrane Collaboration RoB 2 tool.[47] Two reviewers (MLI and MLV) independently conducted the evaluation using Review Manager (RevMan 5.4). Discrepancies in bias ratings were discussed until a consensus was reached. If no agreement was reached, a third reviewer (Reviewer 3) resolved the discrepancy by voting. Disagreements were recorded and analysed to ensure transparency in decision-making.

Studies were evaluated according to the following domains: randomization, bias due to deviations from the intended interventions, bias due to missing outcome data, bias in outcome measurements, and bias in reported outcome selection. Each domain was classified as having a low risk, some concerns, or high risk of bias, and the overall risk of bias was assessed.

6 QUALITY OF EVIDENCE

The quality of evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE).[48] It's was used the software GRADEpro.

7 RESULTS

Search and Selection of Studies

The flowchart of the search and selection of studies is shown in Figure 1. After removing duplicates, 4645 studies were identified based on the titles and abstracts. A total of 21 articles were evaluated, including an important article on patients with fixed orthodontics,[49] which did not have an abstract. However, a request was made to the National Library of Sweden, and the article was obtained.

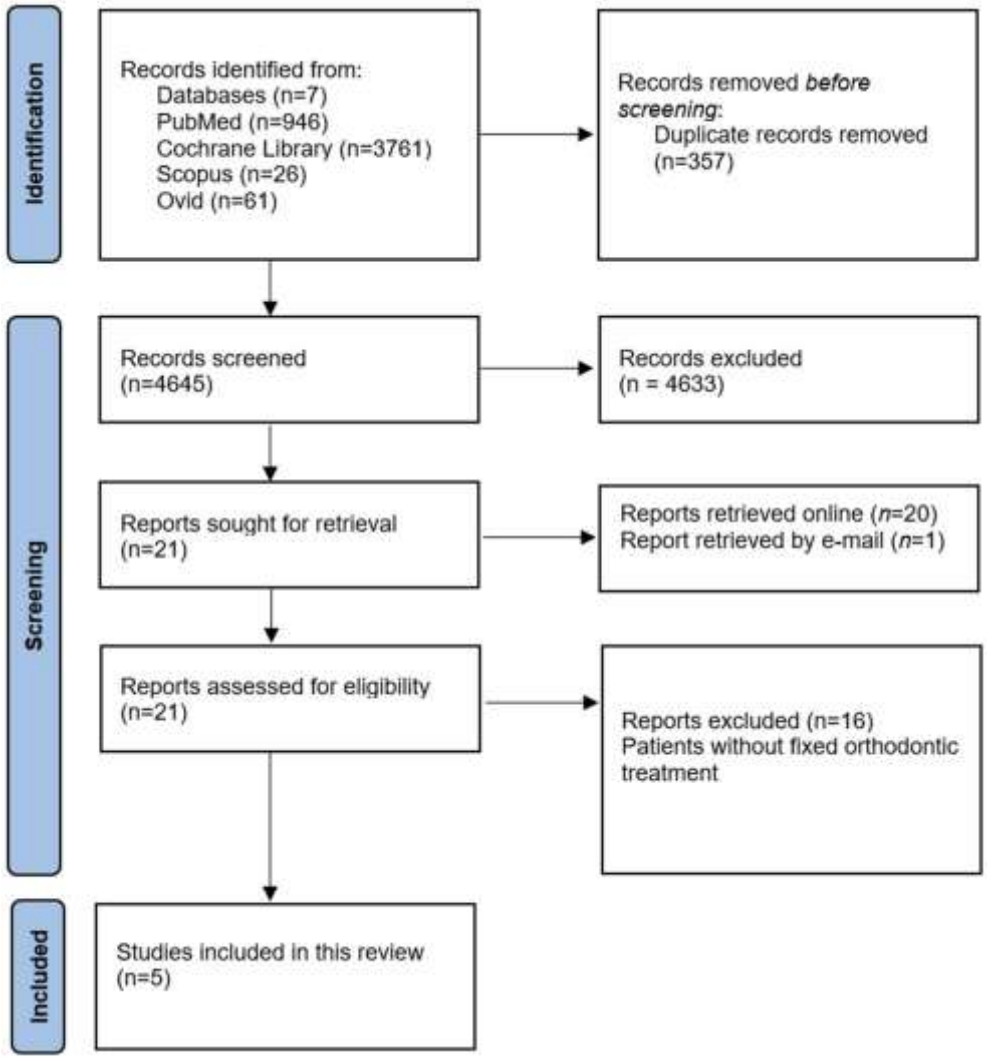


Figure 1 Flow diagram of the selection process. Adapted from Page M, McKenzie J, Bossuyt P, Boutron I, Hoffmann T, Mulrow C, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.[50]

A complete evaluation of 21 articles was performed according to the predefined inclusion criteria. Sixteen studies were excluded because the participants did not undergo fixed orthodontic treatment. A total de five studies were included which shows the lack of studies in patients with fixed orthodontic appliances.

8 CHARACTERISTICS OF THE INCLUDED STUDIES

Among the five included studies, four were randomized controlled clinical trials[5,20,40,49] and one was a clinical trial.[3] All studies were conducted at a single research centre in a university setting, and three trials[3,5,49] were sponsored. None of them mentions the type or brand of fixed orthodontic appliances used. The five studies were performed in patients with fixed orthodontic appliances and no medical history. In terms of oral health, three studies were conducted in

periodontally healthy patients,[3,20,40,49] and the study by Weber et al[5] involved patients with a plaque index greater than 40% throughout the oral cavity and a need for periodontal therapy (Table 2). The daily consumption of chewing gum and the duration of consumption varied across the different studies. In one study, participants consumed 10 pieces of gum daily for 15 minutes over 1 month,[3] participants in another study chewed 4 pieces of gum daily for 15 minutes over 30 days,[5] and participants in another trial chewed 4 pieces of gum daily for 10 minutes over 3 months.[40] In another study, participants chewed 6 pieces of gum daily for 5 minutes over 12 months.[20]

Table 2 Characteristics of the Included Studies

Author, Year	Country, # Center, Setting, Funding	Sample	Age/ Years	Participants' Condition	Dose	Evaluation Time	Consumption Instructions	Types of Chewing Gums Evaluated
Graber et al., 19	United States, single-centre, university, sponsored	First trial: 28 children	10-14.5	Not reported	3 gums per day	Baseline, each month for two occasions, 1, 2, 3, and 4 months	After meals and oral hygiene for 5 minutes, evaluated at 5, 10, 15, 20, 25, and 30 minutes of chewing	G1: sucrose (n=7) G2: sorbitol (n=7) G3: xylitol (n=7) G4: control (n=7)
		Sd trial:62	Not reported	Not reported	3 gums per day	3 months for the baseline value, 6 months, and 3 additional months after chewing	After meals and oral hygiene for 5 minutes, evaluated at 5, 10, 15, 20, 25, and 30 minutes of chewing	G1: xylitol (n=39) G2: sugar-free (n=12) G3: sucrose (n=11)
		Fourth trial: 12	11.5-13	Not reported	6 gums per day	5 days of strict oral hygiene for the baseline value, 1, 2, and 3 months without oral hygiene	After meals and without oral hygiene for 5 minutes, evaluated at 5, 10, 15, 20, 25, and 30 minutes of chewing	G1: xylitol (n=6) G2: sugar-free (n=6)
Isotupa et al., 1995[3]	United States, single-centre, university, sponsored	60 children	8	No medical history and periodontally healthy	2 gums, five times per day	Baseline–1 month	After meals and oral hygiene for 10 minutes	G1: xylitol (n=15) G2: sorbitol (n=15) G3: xylitol y sorbitol mix 4:1 (n=16) G4: xylitol and sorbitol mix 3:2 (n=14)

Cosyn et al., 2006[40]	Belgium, single-centre, university, self-funded	31 adolescents	12.35 ±2.4	No medical history, periodontally healthy, used the same brushing technique, brush and mouthwash	2 gums, twice per day	Baseline–3 months	After meals and oral hygiene for 10 minutes	G1: 800 mg pf chlorhexidine (447 mg of sorbitol and 5 mg of diacetate of CHX) (n=16)
								G2: placebo gum 800 mg (447 mg sorbitol) (n=15)
Masoud et al., 2015[20]	Saudi Arabia, single-centre, university, self-funded	41 adolescents and young adults (baseline), 36 (3 months), 31 (6 months), and 31 participants (12 months)	18.4	No medical history, no temporomandibular disorders, no active caries	2 gums, three times a day; 4 candies, three times a day	Baseline, 3 months, 6, and 12 months	After meals for a minimum of 5 minutes	GA: xylitol gum, 1 g (n=13)
								GB: chewable xylitol mint candies, 0.5 g (n=13)
								GC: no gum (n=12)
Weber et al., 2024[5]	Germany, single-centre, university, sponsored	52 adolescents	11-22	No medical history, plaque index > 40% in the whole mouth, and need for periodontal treatment	1 gum, four times a day	Baseline and 10 and 30 days	After meals for 15 minutes	G1: CovidGum, contains essential oils (cinnamon, lemon, and mint), ginger, ginseng, zinc, quercetin, spermidine, vitamin D3, xylitol, sucralose (n=26)
								G2: sugar-free, sweeteners sorbitol, isomaltose, maltitol syrup, aspartame, barelyasse, flavours, humectant glycerin (n=26)

In all studies, gum consumption occurred after meals and oral hygiene. On the other hand, Graber et al[49] reported four trials within the same article: the first trial lasted more than 6 months, the second trial lasted more than 12 months, the third trial was conducted with mouthwashes (not evaluated), and the fourth trial lasted more than 3 months.

In all five studies, the effects of chewing gum on the oral cavity were measured at baseline[3,5,20,40] and compared over 10 days,[5] 1 month,[3,5] 3 months,[20,40] and 6 and 12 months of consumption.[20,49]

Regarding the therapeutic content of the chewing gum, three studies compared gums with alcohol-derived substances such as xylitol,[3,20,49] different mixtures of xylitol and sorbitol,[3] sucrose,[49] one used chlorhexidine,[40] and another used chewing gums containing essential oils;[5] three studies used chewing gum (with sorbitol) as control,[3,5,40] and two studies did not use any gum as a control,[20,49] all of which are detailed in Table 2.

9 RESULTS OF THE INTERVENTIONS

The effectiveness of the chewing gums against SM was evaluated in two studies[3,20,] which were measured at the salivary level and in the dental plaque. The diagnostic tests and evaluation methods used differed. The plaque index was measured in all the studies,[3,5,20,40] but the evaluation methods used varied across the studies. Gingival bleeding was reported in two trials,[5,40] and only one study reported pH levels in the dental plaque.[49] Different evaluation methods and estimations were used in these studies, so it was not possible to perform a meta-analysis, with the details shown in Tables 3–5.

10 ANTIMICROBIAL EFFECTIVENESS AGAINST SM AT THE SALIVARY LEVEL AND IN DENTAL PLAQUE

The studies included in this review used different tests to evaluate the effects of chewing gums on SM. For example, at the salivary level, approximately 2 mg of plaque was collected from the vestibular surface of the right upper first molar, dried for six days, and tested using the Orion Diagnostics test for SM detection;[3] however, in the study by Masoud et al[20] colony-forming units per millilitre (CFUs/mL) of SM were developed on Dentocult inoculated strips, where SM adhered to the rough surface of the strip according to density, and after a comparison with a model provided by the manufacturer, these units were classified into class 0 (less than 10,000 CFUs/mL), class 1 (less than 100,000 CFUs/mL), class 2 (between 100,000 and 1,000,000 CFUs/mL), and class 3 (more than 1,000,000 CFUs/mL).

In the study by Isotupa et al[3] the effectiveness of chewing gums with different concentrations of xylitol, xylitol– sorbitol (4:1), and xylitol–sorbitol (3:1) was evaluated. After basal measurements and a 1-month follow-up, significant reductions in salivary SM counts were observed: 17% for xylitol gum and 33% for xylitol–sorbitol gum. In contrast, the xylitol–sorbitol (3:1) formulation and the sorbitol gum did not show significant differences in either measure. Masoud et al[20] evaluated the effects at baseline and compared the effectiveness at 3, 6, and 12 months between gums with xylitol, xylitol chewing candies, and no gum, reporting no statistically significant differences within the groups but significant reductions in SM at the third month for the gum or mint groups.

Regarding dental plaque, Isotupa et al[3] collected plaque around the gingival margin and brackets (incisors, canines, and premolars) for 5 minutes and performed immunological determination of SM by immunoblotting. In the study by Masoud et al.[20] SM levels were detected using the Dentocult SMTM test, and samples were collected with a periodontal probe from the buccal surface of the upper right central incisor, the buccal surface of the left first upper molar, the buccal surface of the lower left central incisor, and the lingual surface of the right lower first molar.

In the study by Isotupa et al[3] significant reductions in SM were observed in all three groups that chewed gum with different concentrations of xylitol after one month of consumption. However, the greatest reduction of 29% was observed in the group that consumed the xylitol–sorbitol (4:1) mixture. In the study by Massoud et al[20] the effectiveness of the chewing gums against SM in dental plaque showed a decrease in SM abundance compared to the basal readings for all groups, but significant differences were observed between the groups for the mints at 3 and 6 months, whereas the gums significantly reduced SM abundance at 12 months of use (Table 3).

11 POSTERIOR DENTAL PLAQUE SCORES AFTER CHEWING GUM

The methods for evaluating the amount of dental plaque differed according to studies. In the study by Isotupa et al[3] dental plaque was collected from incisors, canines, and premolars in the area between the gingival margin and the bracket using a curette, collected for 5 minutes, and then weighed on plates to determine the amount of fresh plaque.

Table 3 Quantitative Analysis of Chewing Gums and *Streptococcus Mutans* Levels in Saliva and Dental Plaque

[12]

Author, Year	Diagnostic Test	Evaluated Groups	Saliva					Dental plaque					
			Mean ± SD	Mean ± SD			p	Diagnostic Test	Mean ± SD	Mean ± SD		p	
		Time of Consumption	Baseline	1 month					Baseline	1 month			
Isotupa et al, 1995[3]	Orion Test	G1: xylitol	2.97 ±0.13	2.47±0.85			−17%, p<0,05*	Immunoblotting	2.8± 0.41	2.2±1.01		−20%, p<0.05*	
		G2: 4:1 xylitol and sorbitol mix	2.16±1	1.44±0.95			−33%, p<0,05*		2.44± 0.73	1.69±1.01		−29%, p<0.05*	
		G3: 3:2 xylitol and sorbitol mix	2.29± 1.05	2±0.94			−13%, p>0,05		2.14± 1.23	1.57±0.94		−25%, p<0.05*	
		G4: sorbitol	2.47± 0.85	2.4±0.97			−3%, p>0,05		2.4± 0.63	2.53±0.91		−4%, p>0.05	
Masoud et al, 2015[20]	Prueba Dentocult SMTM.	Time of Consumption	Basal	3 m	6 m	12 m	p>0.05	Dentocult Test	Basal	3 m	6 m	12 m	Baseline vs 3 months, p=0.001*; baseline vs 12 months, p=0.037*
		GA: xylitol gum	NR	−0.4	−0.53	−1.34			NR	−1.76	−1.5	−2.08	
		GB: chewable xylitol mint candies		−1.4	−0.81	−0.87	p>0.05			−2.31	−1.5	−1.87	Baseline vs 3 months, p=0.021*; baseline vs 6 months, p=0.005*
		GC: no gum		−1.3	−0.21	−0.21	p>0.05			−2.97	−2.93	−3.00	Basal vs 3 months, p=0.003*; baseline vs 6 months, p=0.003*; baseline vs 12 months, p=0.003*

Note: * p < 0.05.

Table 4 Quantitative Analysis of Chewing Gums and the Dental Plaque Index

Author, Year	Evaluated Groups	Fresh Dental Plaque (%)						Dry Dental Plaque (%)		
		Examination	Mean ± SD	Mean ± SD			p	Mean ± SD	Mean ± SD	p
Isotupa et al, 1995[3]	G1: xylitol	Plaque collection (incisors, canines, premolars) between the gingival margin and bracket with a curette for 5 minutes, then weighed	Baseline	1 month				Baseline	1 month	
			28.8 ±14.1	16.5±10.7			−43%, p<0.01*	9.4±5.3	5±2.8	−47%, p<0.001*
	G2: 4:1 xylitol and sorbitol mix		29.1±20	19.8±15			−32%, p<0.05*	7.8±5.2	5.5 ±3.8	−29%, p<0.01*
	G3: 3:2 xylitol and sorbitol mix		25.6 ±20.2	17±11.7			−34%, p<0.05*	7.5±5.4	5.4±4	−28%, p<0.05*
	G4: sorbitol		30.1 ±17.8	20.5±9.9			−32%, p<0.05*	8.2±5	5.8 ±2.8	−29%, p<0.05*
Cosyn et al, 2006[40]	G1: chlorhexidine gum	Time of Consumption	Baseline	1 m	2 m	3 m	6 m	p>0.05 within and between groups; −0.12% on the lingual or palatal surface ($p < 0.05$) at 3 months in Group G2.	NE	
	G2: placebo gum (sorbitol)	Plaque index Quigley and Hein	NR	NR	NR	NR	NR			

Masoud et al, 2015[20]	GA: xilitol gum, 1 g.	Time of Consumption	Baseline	3 m.	6 m.	12 m.	Baseline vs 3 months, p=0.001; baseline vs 6 months, p=0.672; baseline vs 12 months, p=0.059	NE
		Simplified Plaque Index (DI-S) by Greene and Vermillion (0–3 rating)	NR	−3.27	−0.42	−1.89		
	GB: chewable xylitol mint candies, 0.5 g			−3.61	−0.57	−0.75	Baseline vs 3 months, p=0.000; baseline vs 6 months, p=0.56; baseline vs 12 months, p=0.45	
	GC: no gum			−3.12	−2.6	−2.64	Baseline vs 3 months, p=0.002; baseline vs 6 months, p=0.009; baseline vs 12 months, p=0.008	
Weber et al, 2024[5]	G1: CovidGum	Time of Consumption	Baseline/ Median	10 days/ Median	1 m/Median		Baseline vs 10 d, p=0.011; 10 d vs 30 d, p> 0.05; baseline vs 30 d, p=0.0023	NE
		Lange et al, Plaque Index	81.4	68	66.6			
	G2: sugar-free, sorbitol		80.4	66.7	64.9		Baseline vs 10 days, p=0.021; 10 days vs 30 days, p> 0.05; baseline vs 30 days, p=0.039	

Note: * $p < 0.05$.

Abbreviations: m, months; SD, standard deviation; NR, not reported; NE, not evaluated.

The sample was subsequently dried at 35 °C for six days and weighed on an analytical balance, after which the amount of dry dental plaque was determined. In the study by Cosyn et al[40] the Quigley and Hein Plaque Index (PI), which was measured at six sites (mesial, central, and distal; both buccal and oral) after plaque disclosure, was used. The scores ranged from 0 to 5.

Masoud et al[20] used the simplified debris index (DI-S) developed by Greene and Vermillion. Six dental surfaces were examined: the buccal surface of the upper right first molar (16B), the buccal surface of the upper right central incisor (11B), the buccal surface of the upper left first molar (26B), the lingual surface of the lower right first molar (46B), the buccal surface of the lower left central incisor (31B), and the lingual surface of the lower left first molar (36L). Each surface was scored based on the amount of plaque covering it: if no plaque was present, it was scored as 0; if plaque covered less than one-third of the crown, it was scored as 1; if plaque covered more than one-third but less than two- thirds of the crown, it was scored as 2; and if plaque covered more than two-thirds of the crown, it was scored as 3. These scores were then summed and divided by six.

Weber et al[5] used the Approximal Plaque Index (API) reported by Lange et al to assess dental plaque accumulation and gingival inflammation. Among the inclusion criteria, patients had to have inadequate oral hygiene, as indicated by an API greater than 40% throughout the mouth.

Isotupa et al[3] compared chewing gums with different concentrations of xylitol, xylitol and sorbitol (4:1), (3:1), and sorbitol alone. At baseline and after one month, the consumption of chewing gums in all the polyol groups reduced the weight of both fresh and dry dental plaque. However, a 43% reduction in fresh plaque weight and a 47% reduction in dry plaque weight were observed in the xylitol group.

In the study by Cosyn et al,[40] two groups of chewing gums were compared: one based on chlorhexidine and the other was a control group with sorbitol. The evaluation was conducted at baseline, one month, two months, and three months. Although the study did not report the obtained results, it suggested no significant differences in plaque levels across the whole mouth, neither within nor between the groups. However, when the evaluated tooth surfaces were analysed, a reduction of 0.12 in plaque levels was observed at lingual or palatal sites at three months ($p=0.05$) for the sorbitol group, whereas the chlorhexidine group also showed a reduction of 0.11, although the difference was not statistically

significant (p=0.07). No significant differences were found in the other evaluated tooth sites.

Masoud et al[20] evaluated the effects at baseline and compared the effectiveness at 3, 6, and 12 months among chewing gums with xylitol, xylitol mint chewable candies, and a control group without gum. A reduction in dental plaque scores was observed in all three groups over the 12-month period; however, this reduction reached statistical significance only in the chewing gum and mint groups at 3 months.

The comparison between groups revealed significant differences in plaque reduction at 12 months, with the control group and the chewing gum group showing greater reductions than the mint group. However, no statistically significant differences were observed between the chewing gum group and the control group.

Weber et al[5] compared two chewing gum formulations: one containing essential oils and the other based on sorbitol. Evaluations were conducted at baseline, after 10 days, and after 30 days of consumption. In both groups, a greater reduction was observed at 10 days than at 30 days, with a decrease of 68% in the essential oil group and 66.7% in the sorbitol group. No significant differences were observed between the groups, but within each group a significant difference from the baseline level was identified at both 10 and 30 days for the groups that chewed gum with essential oils and the sorbitol group (Table 4).

12 GINGIVAL INDEX AND BLEEDING ON PROBING

The indices used to assess gingival health and bleeding on probing varied among the included studies. Cosyn et al[40] used the Bleeding on Probing Index (BoPi), which was measured at six points (mesial, central, and distal on both the buccal and palatal surfaces). The scores were as follows: 0 for no bleeding; 1 for spot bleeding within 10 seconds; and 2 for profuse bleeding within 10 seconds. In the trial by Weber et al,[5] the Papillary Bleeding Index of Saxer and Mühlemann was used in the trial by Cosyn et al,[40] who compared two groups of chewing gums: the first containing chlorhexidine and the second serving as a control group with sorbitol. These groups were evaluated over 30, 60, and 90 days, but no significant results were reported. The study concluded that the differences between the two groups were not significant. However, in the placebo group, a reduction in bleeding on probing was observed at two months (0.10) and three months (0.19) compared with baseline. In contrast, the chlorhexidine group showed a statistically significant reduction only

at two months (0.23) relative to the baseline value. With respect to the examined sites, a greater reduction was observed at the palatal level in both the chlorhexidine group (0.28) and the placebo group (0.29). Moreover, Weber et al[5] compared a group of chewing gums containing essential oils and a sorbitol-based gum. Evaluations were conducted at baseline, after 10 days, and after one month. No significant differences were observed between the groups; however, a statistically significant reduction in the median values was observed for both gum groups from baseline to 10 days and from baseline to 30 days (Table 5).

13 PLAQUE PH LEVEL

The study by Graber et al[49] reported four trials; however, one was not included in this review because it was conducted with mouth rinses. The plaque pH was measured with a pH meter in the gingival area of the upper right lateral incisor and the lower left lateral incisor for 90 seconds.

The first trial did not report average values between groups; however, chewing gum with xylitol significantly increased pH levels, with a cumulative effect over four months, whereas changes in the control group were insignificant. In the second trial, the pH was measured at six months, and the results revealed no significant decrease in the sucrose gum group, with no values falling below 6.37. Moreover, in the sugar-free gum group, no changes were observed for up

to 30 minutes, whereas the xylitol gum group presented a significant increase in plaque pH for up to 30 minutes.

The fourth trial also did not report detailed average values but concluded that xylitol gum produced a significant and consistent increase in pH levels up to the third month. On the other hand, the addition of sugar-free gum did not cause any pH changes during the first week. Additionally, without chewing gum or brushing teeth for the first three days, the pH did not drop below 6.0 in any participant.

14. RISK OF BIAS ASSESSMENT

Based on the evaluation of the domains, one study was considered to have a low risk of bias,[5] one trial was rated with some concern,[40] whereas three studies were determined to have a high risk of bias (Figure 2).

According to the relative frequency of each domain of the risk of bias based on the included studies, more than 50% presented a high risk of bias,[3,20,49] and less than 25% were at low risk of bias[5] (Figure 3).

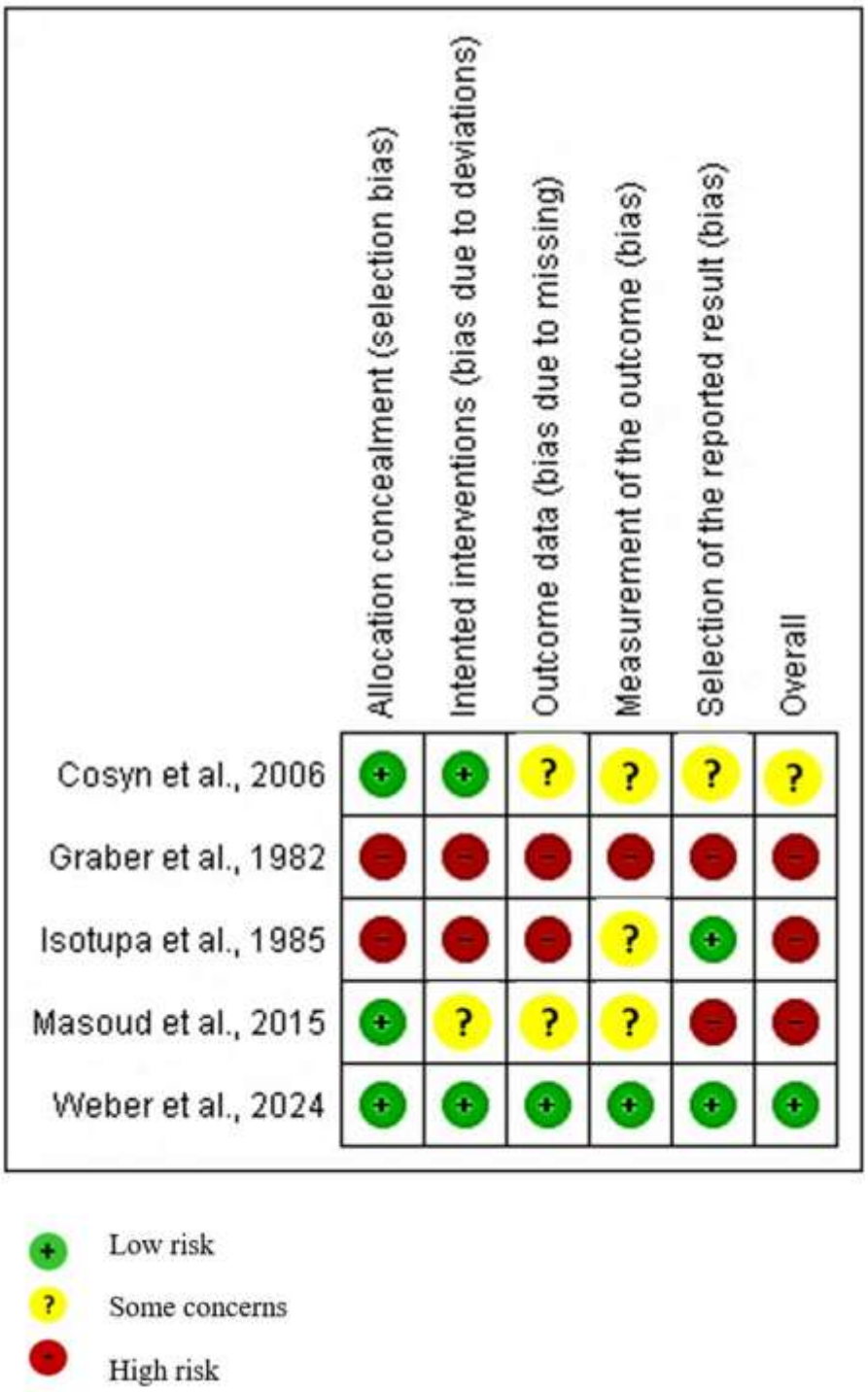


Figure 2 Summary of the risk of bias for each domain in the included studies.

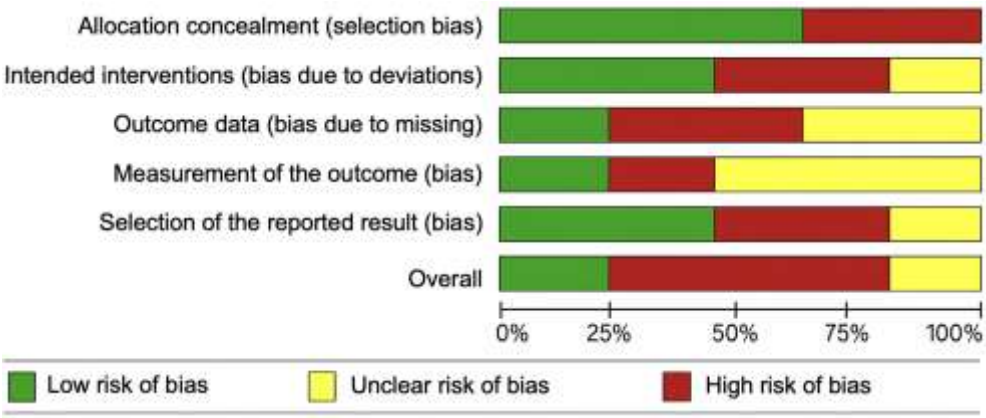


Figure 3 Percentage of the risk of bias for each domain in the included studies.

The high risk of bias seriously weakens confidence in the results, whereas a trial with some concern raises doubts about the findings. In contrast, the results of a low-risk-of-bias study are unlikely to be significantly altered by bias.[47]

15 QUALITY OF EVIDENCE

GRADE evidence profile was completed for all outcomes. Level of evidence was high for reductions in SM indicates that we are very confident that the true effect lies close to that of the estimate of the effect. It is suggested to use chewing gum (4:1 xylitol and sorbitol mix or xylitol) to decrease the levels of SM in saliva; dental plaque index and Gingival bleeding index were low indicates that our confidence in the effect estimate is limited and assessed of pH saliva was very low shows that we have very little confidence in the effect estimate. (Table 6) Different evaluation methods and estimations were used in these studies, so it was not possible to estimate absolute or relative effects.

Table 6 Summary of Findings of Antimicrobial Effectiveness and Periodontal Actions of Sugar-Free Chewing Gums Derived in Patients with Fixed Orthodontics Compared with Baseline with GRADE Certainty

Certainty Assessment							Certainty	Importance
No of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Considerations		
Streptococcus mutans (assessed with: levels in saliva and dental plaque in reference to the baseline average)								
2	Randomised trials	Not serious	Not serious	Not serious	Not serious	None	⊕⊕⊕⊕High	Important
Dental plaque index (assessed with: in the dental plaque index in reference to the baseline average)								
4	Randomised trials	Not serious	Serious[a]	Not Serious	Serious[b]	None	⊕⊕◯◯Low[a,b]	Important
Gingival bleeding index (assessed with: the gingival bleeding index in reference to the baseline average)								
2	Randomised trials	Not serious	Serious[a]	Not serious	serious[a]	None	⊕⊕◯◯Low[a]	Important
pH salival (assessed with: pH salival in reference to the baseline average)								
1	Randomised trials	Not serious	Very serious[b]	Not serious	Very serious[b]	None	⊕◯◯◯Very low[b]	Important

Notes: a. One study does not report detailed results and the method evaluated differs in the different studies b. Does not report the result

16 DISCUSSION

The limited number of randomized clinical trials, combined with the heterogeneity in their approaches and outcome evaluation methods, prevents the execution of a rigorous quantitative analysis.

Furthermore, chewing gum is frequently used by patients who, due to adverse situations—such as arm fractures and other accidents—are unable to maintain proper daily oral hygiene.[3] Furthermore, the consumption of chewing gum is significantly greater in children than in adolescents.[16,51] The use of sugar-free gum could represent a far-reaching preventive strategy in the field of public dental health worldwide.[52]

The cariostatic effects of sugar-free chewing gum are partly due to the enhancement of the mechanical cleansing action provided by saliva, which facilitates the removal of food debris. Additionally, this type of gum stimulates an increase in plaque pH, which is attributed to increased concentrations of remineralizing ions and bicarbonate in stimulated saliva.[15] These benefits can be particularly relevant for patients at high risk of developing

periodontal diseases and dental caries, such as those undergoing treatment with fixed orthodontic appliances.

The most common polyols used in chewing gum are xylitol, sorbitol, mannitol, and maltitol.[53] During the caries process, a fermentable substrate is considered maintained on or within the dental structure. The fermentation of sorbitol could be of some importance since it is generally fermented by SM and oral lactobacilli. Most of the analysed SM serotypes fermented sorbitol. Frequent exposure of the mouth to sorbitol increases acid production from sorbitol in dental plaque and the growth of SM.[3]

The use of sorbitol-containing chewing gum for three months resulted in persistent flora that was adapted to sorbitol; all the study subjects had a high capacity to metabolize sorbitol even 12 weeks after the study ended. Formic acid, acetic acid, lactic acid, and ethanol were the main catabolites of sorbitol. Compared with the use of sorbitol gum, the regular use of xylitol-containing chewing gum helps reduce the acidogenic potential of dental plaque.[3]

Chewing gums containing sorbitol or high proportions of sorbitol and xylitol are less expensive to manufacture, although their effect on dental plaque should be considered lower than that of xylitol-only chewing gum.[3]

The chewing time can also affect the results in the oral cavity. Prolonged chewing (20 to 30 minutes) masks the potential specific effects of polyols. An effective chewing duration of 10 minutes is considered optimal to preserve any selective effect of polyols on dental plaque.[3]

Traditionally, orthodontic patients are advised not to chew gum; however, the absence of damage to the appliances, the lack of excessive adherence,[3] the absence of symptoms in the temporomandibular joint,[20] and the absence of bracket detachment[5] suggest that this restriction may no longer be necessary and that chewing gum could even be encouraged. Masoud et al[20] showed not statistically significant difference in broken brackets between xylitol chewing gum or chewable mints.

With respect to the reduction in the SM count in dental plaque, Isotupa et al[3] and Masoud et al[20] observed no differences between the evaluated chewing gums or the absence of gum; however, significant differences within each group from baseline values to 30 days of consumption or[3] at 12 months were observed,[20] with a greater reduction in the SM count detected for the xylitol–sorbitol mixture (4:1) than for xylitol gum[20] (Table 2).

Regarding the scores of fresh dental plaque, Isotupa et al[3] reported no significant differences between the different chewing gum groups (xylitol, xylitol–sorbitol mixture, and sorbitol). However, significant differences were observed in all groups after one month of consumption, with the greatest plaque reduction detected in the xylitol group, whereas Cosyn et al[40] reported no differences between the chewing gum groups (chlorhexidine and sorbitol). However, they reported a greater reduction in plaque at the palatal area in the sorbitol group after three months of consumption. Masoud et al[20] documented significant differences between groups (xylitol gum, xylitol mints, and no gum), with xylitol gum and mints proving to be more effective after 12 months of consumption. Weber et al[5] also did not observe significant differences between the chewing gum groups (essential oils and sorbitol). However, within each group, a significant reduction in dental plaque was observed at 10 and 30 days of consumption (Table 3).

Although xylitol is not cariogenic, we cannot recommend its use as a caries prevention measure, as it did not provide any measurable benefit compared with a control group that received oral hygiene instructions. Additionally, participants'

awareness of their involvement in the study may have influenced their ability to improve their oral hygiene, leading to better results in the placebo group (without chewing gum).[20] Sorbitol gum was found to be more effective than chlorhexidine;[20] however, in the oral areas, plaque levels were not affected at any time in either group. These observations suggest that chewing gum induces a mechanical cleaning effect on the lingual/palatal areas.[40]

Regarding the gingival index and bleeding on probing, Weber et al[5] reported no significant difference between the essential oil and sorbitol chewing gum groups, which could be explained by the fact that the 10-day to one-month period of use of the test chewing gum may have been too short to detect differences in the Papillary Bleeding Index (PBI) between the groups, as the PBI is a parameter used to monitor oral hygiene in the medium and long term. Similar results were obtained by Cosyn et al[40] between chlorhexidine and sorbitol chewing gum groups, with a consumption period of three months.

In the second trial, Graber et al[49] demonstrated the efficacy of xylitol in increasing plaque pH after six months of consumption. In the fourth trial, they also noted an increase in plaque pH after consuming two xylitol chewing gums per day for three months. This

effect is possibly due to the chewing action, which produces a buffering effect and increases salivary flow, influencing pH levels.

In short-term studies and in participants without orthodontic appliances, xylitol and sorbitol chewing gums were more effective at reducing periodontal indices than CPP-ACP chewing gums were (20 minutes of chewing, three times a day, for 30 days).[15] Significantly reduced dental plaque levels, the index, and bleeding on probing were observed for both xylitol and sorbitol chewing gums.[35]

Akgül et al[32] also described the efficacy of a chewing gum containing 0.9 g of xylitol (chewed for 10 minutes, with a daily dose of 5.4 g for three weeks) in reducing the gingival index, dental plaque, and SM count. Söderling et al[39] reported a reduction in SM levels in both stimulated and unstimulated saliva with xylitol chewing gum, as well as with sorbitol gum, by the fifth week of chewing.

Moreover, Ghasemi et al[33] found that both xylitol chewing gum and probiotic yogurt effectively reduced the SM colony-forming units on day one, the second week, and the fourth week (dose: 5.58 g/day).

On the other hand, long-term studies revealed additional results regarding the efficacy of chewing xylitol gum for 13 months in pregnant mothers (starting from the sixth month of pregnancy), revealing a reduction in the duration of SM presence in the oral cavity of their children compared with mothers who did not consume gum.[34]

However, some studies have shown that mastic gum is more effective than xylitol + sorbitol gum, resulting in greater reductions in bacterial growth and dental plaque formation on teeth.[28]

The recommended dosage can range from 6.44 g/day to 10.32 g/day for six months of the primary xylitol-based chewing gum, with a minimum chewing time of 5 minutes, to reduce SM levels in dental plaque and unstimulated saliva.[37]

After the consumption of foods such as cereals, the pH decreased from 6.4 to 4.8 within 20 minutes. However, when chewing sorbitol-based gum, an increase in pH up to 5.5 was observed, indicating that chewing gum after eating causes a transient increase in the plaque pH. Although this study did not evaluate xylitol gum, other research suggests that this formulation may maintain a relatively high pH in the plaque even after chewing stops.[54]

Finally, in a systematic review, Muniz et al[55] determined that of different sugar-free chewing gums containing green tea + xylitol showed better antiplaque effect over negative controls in patients without fixed orthodontic treatment. However, cautious interpretation is required due to the low number of direct comparisons arms. These shortcomings underscore the need for RCTs with mostly head-to-head comparison that provide more conclusive evidence.

17 LIMITATIONS

Due to the limited information, the variability of evaluation methods across different studies, and the small number of clinical trials, the diversity in the time of chewing gum consumption, the research of the effects of chewing gums formulated with different therapeutic agents should use standardized tools for measuring outcomes. The lack of studies that assess their antibacterial efficacy and periodontal actions in detail highlights the need for further research to define their roles precisely in patients with fixed appliances. In addition, participant's knowledge of the research can influence the results improving the quality of oral hygiene.

18 CONCLUSIONS

The different types of chewing gums induced significant changes that contributed to improving oral health in patients with fixed orthodontics; the quality of evidence suggests that chewing gums (4:1 xylitol and sorbitol mix or xylitol) could decrease the level of SM in saliva. It is important to emphasize that a minimum of one month of consumption and 10 minutes is recommended to verify changes in the oral cavity. Therefore, the use of sugar-free chewing gums derived from alcohols or plant-based extracts can help improve oral cavity conditions, which are always supported by proper oral hygiene and topical fluoride application. However, the heterogeneity of the studies limits the generalization of these findings to other outcomes (Dental plaque index, Gingival bleeding index, pH saliva) highlighting the need for larger and longer clinical trials to confirm their efficacy.

19. COLLABORATORS

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21 DISCLOSURE

The authors report no conflicts of interest related to this work.

22 REFERENCES

1. Aksoy A, Duran N, Toroglu S, Koksal F. Short-term effect of mastic gum on salivary concentrations of cariogenic bacteria in orthodontic patients. *Angle Orthod*. 2007;77(1):124–128. doi:10.2319/122205-455R.1
2. Duś I, Jedliński M, Padella S, Corridore D, Mazur M. Fixed appliances orthodontic therapy as a risk factor for caries development: systematic review. *Adv Clin Exp Med*. 2024;33(10):1153–1161. doi:10.17219/acem/174444
3. Isotupa KP, Gunn S, Chen CY, Lopatin D, Mäkinen KK. Effect of polyol gums on dental plaque in orthodontic patients. *Am J Orthod Dentofac Orthop*. 1995;107(5):497–504. doi:10.1016/S0889-5406(95)70117-6
4. Lombardo L, Yö O, Ö G, Panza C, Scuzzo G, Siciliani G. Changes in the oral environment after placement of lingual and labial orthodontic appliances. *Prog Orthod*. 2013;14(1):28. doi:10.1186/2196-1042-14-28
5. Weber J, Scholz K, Schenke I, et al. Randomized controlled clinical trial on the efficacy of a novel antimicrobial chewing gum in reducing plaque and gingivitis in adolescent orthodontic patients. *Clin Oral Investig*. 2024;28(5):1–9. doi:10.1007/s00784-024-05669-4
6. Lara E, Montiel N, Sánchez L, Alanís J. Effect of orthodontic treatment on saliva, plaque and the levels of Streptococcus mutans and Lactobacillus. *Med Oral Patol Oral Cir Bucal*. 2010;15(6):e924–9. doi:10.4317/medoral.15.e924
7. Muñoz LF, Uribe AM, Reyes MC, Castro LA, Rodríguez MJ. Salivary Streptococcus mutans colony-forming unit count in patients with and without orthodontic appliances. *Acta odontol Latinoam*. 2022;35(3):171–177. doi:10.54589/aol.35/3/171
8. Manuelli M, Marcolina M, Nardi N, et al. Oral mucosal complications in orthodontic treatment. *Minerva Stomatol*. 2019;68(2):84–88. doi:10.23736/S0026-4970.18.04127-4
9. Mummolo S, Tieri M, Nota A, et al. Salivary concentrations of Streptococcus mutans and Lactobacilli during an orthodontic treatment. An observational study comparing fixed and removable orthodontic appliances. *Clin Exp Dent Res*. 2020;6(2):181–187. doi:10.1002/cre2.261

10. Marincak Z, Rousi M, Cvanova M, et al. Effect of fixed orthodontic appliances on gingival status and oral microbiota: a pilot study. *BMC Oral Health*. 2022;22(1):1–12. doi:10.1186/s12903-022-02511-9
11. Cortelli S, Cortelli J, Shang H, Costa R, Charles C. Gingival health benefits of essential-oil and cetylpyridinium chloride mouthrinses: a 6-month randomized clinical study. *Am J Dent*. 2014;27(3):119–126.
12. Keukenmeester R, Slot D, Rosema N, Van Loveren C, Van der Weijden G. Effects of sugar-free chewing gum sweetened with xylitol or maltitol on the development of gingivitis and plaque: a randomized clinical trial. *Int J Dent Hyg*. 2014;12(4):238–244. doi:10.1111/idh.12071
13. Lima M, Jiménez D, Porras C, Maurat K, Álvarez D. Efectos de azúcares totales sustitutos de sacarosa en la salud bucal. Revisión bibliográfica. *Rev Eug Esp*. 2022;16(2):101–113.
14. Wessel S, Van der Mei H, Maitra A, Dodds M, Busscher H. Potential benefits of chewing gum for the delivery of oral therapeutics and its possible role in oral healthcare. *Expert Opin Drug Deliv*. 2016;13(10):1421–1431. doi:10.1080/17425247.2016.1193154
15. Meehrabkhani M, Parisay I, Mastoory N, Doghai VB. Effect of casein phosphopeptide amorphous calcium phosphate and xylitol chewing gums, and probiotic yogurt on periodontal parameters: a randomized clinical trial. *Front Dent*. 2021;18(35):1–11. doi:10.18502/fid.v18i35.7339.
16. Martyn D, Lau A. Chewing gum consumption in the United States among children, adolescents and adults. *Food Additives &amp*. 2019;36 (3):350–358. doi:10.1080/19440049.2019.1567944
17. Asif M, Saleem M, Saadullah M, Yaseen HS, Al Zarzour R. COVID-19 and therapy with essential oils having antiviral, anti-inflammatory, and immunomodulatory properties. *Inflammopharmacology*. 2020;28(5):1153–1161. doi:10.1007/s10787-020-00744-0
18. Pfab F, Buelow-Johansen B, Alber D, Kriner M, Kornmann O, Stuermer M. Reduction of SARS-CoV-2 viral load in exhaled air by antiseptic chewing gum: a pilot trial. *Infection*. 2023;51(4):881–885. doi:10.1007/s15010-022-01944-2
19. Rafeek R, Carrington C, Gomez A, et al. Xylitol and sorbitol effects on the microbiome of saliva and plaque. *J Oral Microbiol*. 2018;11(1):1

doi:10.1080/20002297.2018.1536181

20. Masoud MI, Allarakia R, Alamoudi NM, Nalliah R, Allareddy V. Long-term clinical and bacterial effects of xylitol on patients with fixed orthodontic appliances. *Prog Orthod*. 2015;16(1):35. doi:10.1186/s40510-015-0103-z
21. Nasseripour M, Newton JT, Warburton F, et al. A systematic review and meta-analysis of the role of sugar-free chewing gum on Streptococcus mutans. *BMC Oral Health*. 2021;21(1):1–11. doi:10.1186/s12903-021-01517-z
22. Benahmed AG, Gasmi A, Arshad M, et al. Health benefits of xylitol. *Appl Microbio Biotechnol*. 2020;17(104):7225–7237. doi:10.1007/s00253- 020-10708-7
23. Holgerson P, Sjöström I, Stecksén-Blicks C, Twetman S. Dental plaque formation and salivary mutans streptococci in schoolchildren after use of xylitol-containing chewing gum. *Int J Paediatr Dent*. 2007;17(2):79–85. doi:10.1111/j.1365-263X.2006.00808.x
24. Aluckal E, Ankola A. Effectiveness of xylitol and polyol chewing gum on salivary streptococcus mutans in children: a randomized controlled trial. *Indian J Dent Res*. 2018;29(4):445–449. doi:10.4103/ijdr.IJDR_307_16
25. Cocco F, Cagetti MG, Majdub O, Campus G. Concentration in saliva and antibacterial effect of Xylitol chewing gum: in vivo and in vitro study. *Appl Sci*. 2020;10(8):1–11. doi:10.3390/APP10082900
26. Cocco F, Carta G, Cagetti MG, Strohmenger L, Lingström P, Campus G. The caries preventive effect of 1-year use of low-dose xylitol chewing gum. A randomized placebo-controlled clinical trial in high-caries-risk adults. *Clin Oral Invest*. 2017;21(21):2733–2740. doi:10.1007/s00784-017-2075-5
27. Chaudhary S, Shahiwala A. Medicated chewing gum- a novel drug delivery system. *Expert Opin Drug Deliv*. 2010;7(7):871–885. doi:10.1517/ 17425247.2010.493554
28. Takahashi K, Fukazawa M, Motohira H, Ochiai K, Nishikawa H, Miyata T. A pilot study on antiplaque effects of mastic chewing gum in the oral cavity. *J Periodontol*. 2003;74(4):501–505. doi:10.1902/jop.2003.74.4.501
29. Takeuchi K, Asakawa M, Hashiba T, Takeshita T, Saeki Y, Yamashita Y. Effects of xylitol-containing chewing gum on the oral microbiota. *J Oral Sci*. 2018;60(4):588–594. doi:10.2334/josnusd.17-0446

30. Hashiba T, Takeuchi K, Shimazaki Y, Takeshita T, Yamashita Y. Chewing xylitol gum improves self-rated and objective indicators of oral health status under conditions interrupting regular oral hygiene. *Tohoku J Exp Med*. 2015;235(1):39–46. doi:10.1620/tjem.235.39.Correspondence
31. Burt BA. The use of sorbitol- and xylitol-sweetened chewing gum in caries control. *J Am Dent Assoc*. 2006;137(2):190–196. doi:10.14219/jada. archive.2006.0144
32. Akgül Ö, Topaloğlu Ak A, Zorlu S, Öner Özdaş D, Uslu M, Çayirgan D. Effects of short-term xylitol chewing gum on pro-inflammatory cytokines and Streptococcus mutans: a randomised, placebo-controlled trial. *Int J Clin Pr*. 2020;74(9):1–8. doi:10.1111/ijcp.13623
33. Ghasemi E, Mazaheri R, Tahmourespour A. Effect of probiotic yogurt and xylitol-containing chewing gums on salivary s mutans count. *J Clin Pediatr Dent*. 2017;41(4):257–263. doi:10.17796/1053-4628-41.4.257
34. Nakai Y, Shinga-Ishihara C, Kaji M, Moriya K, Murakami-Yamanaka K, Takimura M. Xylitol gum and maternal transmission of mutans streptococci. *J Dent Res*. 2010;89(1):56–60. doi:10.1177/0022034509352958
35. Saheer P, Parmar P, Majid S, Bashyam M, Kousalya P, Marriette T. Effect of sugar-free chewing gum on plaque and gingivitis among 14–15-year- old school children: a randomized controlled trial. *Indian J Dent Res*. 2019;1(30):61–66. doi:10.4103/ijdr.IJDR_247_17
36. Lif P, Stecksén-Blicks C, Sjöström I, Öberg M, Twetman S. Xylitol concentration in saliva and dental plaque after use of various xylitol-containing products. *Caries Res*. 2006;40(5):393–397. doi:10.1159/000094284
37. Milgrom P, Ly KA, Roberts MC, Rothen M, Mueller G, Yamaguchi DK. Mutans streptococci dose response to xylitol chewing gum. *J Dent Res*. 2006;85(2):177–181. doi:10.1177/154405910608500212
38. Söderling E, Pienihäkkinen K. Effects of xylitol and erythritol consumption on mutans streptococci and the oral microbiota: a systematic review. *Acta Odontol Scand*. 2020;78(8):599–608. doi:10.1080/00016357.2020.1788721
39. Söderling E, ElSalhy M, Honkala E, et al. Effects of short-term xylitol gum chewing on the oral microbiome. *Clin Oral Investig*. 2015;19 (2):237–244. doi:10.1007/s00784-014-1229-y

40. Cosyn J, Verelst K. An efficacy and safety analysis of a chlorhexidine chewing gum in young orthodontic patients. *J Clin Periodontol*. 2006;33 (12):894–899. doi:10.1111/j.1600-051X.2006.00997.x
41. Oza S, Patel K, Bhosale S, Gupta R, Choudhary D, Choudhary D. To determine the effect of chewing gum containing xylitol and sorbitol on mutans streptococci and Lactobacilli count in saliva, plaque, and gingival health and to compare the efficacy of chewing gums. *J Int Soc Prev Communit Dent*. 2018;(8):354–360. doi:10.4103/jispcd.JISPCD_54_18
42. Shakhsi M, Hedayatipanah M, Torkzaban P, Mohammadi T, Zeeshan S, Ahmed Z. A chewing gum containing ethylenediaminetetraaceticacid (EDTA), methyl sulfonyl methane (MSM) and xylitol works comparable to chlorehexidine mouthrinse. *Sci Rep*. 2024;14(1):1–8. doi:10.1038/ s41598-024-79551-4
43. Smith CA, Higham SM, Smith PW, Verran J. The effect of chewing urea-containing gum on plaque acidogenic and alkaligenic parameters. *Caries Res*. 2004;38(2):124–129. doi:10.1159/000075936
44. Tulsani S, Chikkanarasaiah N, Siddaiah S, Krishnamurthy N. The effect of Propolis and Xylitol chewing gums on salivary Streptococcus mutans count: a clinical trial. *Indian J Dent Res*. 2014;25(6):737–741. doi:10.4103/0970-9290.152182
45. Meto A, Colombari B, Odorici A, et al. Antibacterial effects of microrepair® BIOMA-based toothpaste and chewing gum on orthodontic elastics contaminated in vitro with saliva from healthy donors: a pilot study. *Appl Sci*. 2020;10(19):1–13. doi:10.3390/app10196721
46. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Sys Rev*. 2016;5(1):1–10. doi:10.1186/s13643-016-0384-4
47. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019;366:1–8. doi:10.1136/bmj.l4898
48. Prasad M. Introduction to the GRADE tool for rating certainty in evidence and recommendations. *Clin Epidemiol Glob Heal*. 2024;25:1–5. doi:10.1016/j.cegh.2023.101484
49. Graber T, Muller T, Bathia V. The effect of xylitol gum and rinses on plaque acidogenesis in patients with fixed orthodontic appliances. *Swed Dent J Suppl*. 1982;15:41–55.

50. McKenzie J, Bossuyt P, Boutron I, et al. he PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi:10.1136/bmj.n71
51. Hearty Á, Lau A, Roberts A. Chewing gum intake in Europe: a survey of intakes in France. *Food Addit Contam Part a Chem Anal Control Expo Risk Assess*. 2014;31(7):1147–1157. doi:10.1080/19440049.2014.913104
52. Zimmer S, Spyra A, Kreimendahl F, Blaich C, Rychlik R. Elevating the use of sugar-free chewing gum in Germany: cost saving and caries prevention. *Acta Odontol Scand*. 2018;76(6):407–414. doi:10.1080/00016357.2018.1487994
53. Keukenmeester R, Slot D, Putt M, der WV. The effect of sugar-free chewing gum on plaque and clinical parameters of gingival inflammation: a systematic review. *Int J Dent Hyg*. 2012;10(13):1–13. doi:10.1111/j.1601-5037.2012.00562.x
54. Lee I, Schachetele C. Effect of gum chewing following food ingestion on the pH of interproximal dental plaque. *Quintessence Int*. 1992;23 (7):455–459.
55. Muniz F, Zanatta F, Muñoz M, Aguiar L, Silva F, Montagner A. Antiplaque and antigingivitis efficacy of medicated and non-medicated sugar-free chewing gum as adjuncts to toothbrushing: systematic review and network meta-analysis. *Clin Oral Investig*. 2022;26(2):1155–1172. doi:10.1007/ s00784-021-04264-1.