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# Impact of Xylitol chewing gum on levels of oral *Streptococcus mutans*. A systematic review

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## ABSTRACT

**Objectives.** This systematic review evaluates the effectiveness of xylitol in combating *Streptococcus mutans,* a key bacterium associated with dental caries.

**Methods.** We performed a search across Scopus, Open Grey, PubMed, Science Direct, and EBSCO databases. After screening and excluding articles that did not meet our predefined inclusion criteria, we selected seven out of the eighty-nine initially identified articles. Data extraction was carried out in three stages: identification, screening, and assessment of eligibility.

**Results.** Among the studies included in this review, six were randomized clinical trials, and one was a before-and-after comparison. Most of these studies indicate that xylitol chewing gum may effectively reduce *S. mutans* counts, potentially lowering the risk of dental caries.

**Conclusion.** The reviewed studies show that xylitol chewing gum positively affects both the quality and quantity of S. mutans. It inhibits *S. mutans* adhesion to tooth surfaces, reduces the production of sticky substances, and alters the bacteria's morphology. Consequently, this leads to improvements in plaque index, gingival index, and DMFT scores.

**Keywords:** Xylitol, *Streptococcus mutans,* cariogenic, dental caries, chewing gum

## INTRODUCTION

Dental caries is a major global public health issue [1]. Bacterial colonization of human teeth begins as soon as they erupt. Salivary proteins and glycoproteins form an acquired enamel pellicle on the enamel surface, which facilitates the adhesion of primary plaque colonizers. Although early colonizers are predominantly Streptococcus species, dental plaque eventually hosts a diverse array of bacterial species [2]. The “specific plaque hypothesis” posits that certain plaque species, particularly *Streptococcus mutans*, are the main contributors to dental decay. Isolated by J.K. Clark in 1924, S. mutans has long been considered a primary etiological agent in the development of dental caries [2,3].

Xylitol, a five-carbon sugar alcohol, is commercially derived from xylan hemicelluloses found in corn cobs and hardwood trees. It is commonly used in “sugar-free” chewing gum and acts as an early intervention to reduce caries prevalence by decreasing the amount of *S. mutans* in the oral cavity. Xylitol has been shown to limit dental caries formation, reduce plaque accumulation and metabolic acid production, inhibit the growth and metabolism of Streptococci, and support remineralization. Its non-fermentable nature prevents the production of lactic acid and glucans, which contribute to plaque stickiness [4]. Additionally, xylitol may enhance ammonia production in plaque, potentially neutralizing lactic acid. Numerous studies have demonstrated that xylitol inhibits *S. mutans* adhesion by affecting extracellular polysaccharides involved in plaque formation. While these studies indicate that xylitol effectively reduces *S. mutans* levels, further research is needed to explore its impact on the virulence and morphology of S. mutans [5].

Existing literature on xylitol and its effects on dental caries presents several limitations and potential biases. Methodological variations, such as dif-

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ferences in xylitol dosage, frequency of use, and study duration, contribute to inconsistencies in the results. Additionally, some studies may be influenced by conflicts of interest due to funding from companies that produce xylitol products. These factors can introduce variability and bias in evaluating xylitol's efficacy [6-9].

Currently, the emphasis is on caries prevention rather than treatment, with xylitol being a prominent focus of research in this area. This systematic review aims to evaluate recent studies and previous literature to determine the effectiveness of xylitol chewing gum in reducing S. mutans levels and preventing dental caries. The hypothesis guiding this review is that xylitol gum significantly decreases S. mutans levels and the prevalence of dental caries.

## METHOD

### Protocol of registration

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The study protocol has been registered with the Open Science Framework (OSF) and can be accessed at: [https://osf.io/uzbwn/](https://osf.io/uzbwn/).

### Focused Question

How does xylitol chewing gum impact the count of *S. mutans* and its cariogenic properties?

### Inclusion Criteria

Studies published in English.
Studies published from the 1970s onwards.
Participants using xylitol chewing gum.
Peer-reviewed articles.
Focused exclusively on S. mutans.
Clear and consistent reporting of outcomes.
Original research studies.
Includes both children and adults.
Xylitol gum used in any concentration, volume, frequency, or duration, alongside oral hygiene practices.

### Exclusion Criteria

Studies published in languages other than English.
Studies published before the 1970s.
Participants using gums with other free sugars instead of xylitol.
Non-peer-reviewed articles.
Case reports or abstracts.
Self-reported outcomes.
Reviews and editorials.
Studies focusing on bacteria other than *S. mutans.*

### Interventions

The review includes studies where xylitol chewing was the primary intervention.

### Outcome

The review focuses on specific outcomes related to *S. mutans*, including its count, trends (especially any declines), and changes in mean or percentage. It also gathers information on the positive effects of xylitol reported in trials, methods to enhance acceptance and implementation, and factors that might influence the results.

### Data Sources and Search

An information specialist designed and conducted the search strategy, applying it to each database using both MeSH terms and free-text search terms. The terms used included “chewing gum,“ “xylitol,” “sorbitol,” “caries,” “xerostomia,” “periodontal disease,” and *S. mutans**. The comprehensive search strategy was tailored for all relevant databases, including PubMed, Open Grey, Scopus, Science Direct, and EBSCO, provided by the University of Sharjah library. Searches were performed simultaneously across these multiple online databases.

### Study Selection

Seven reviewers independently screened titles and abstracts based on the research topic and inclusion/exclusion criteria. Eligibility for full-text studies was confirmed for all relevant articles. In cases of disagreement among reviewers, a third reviewer was consulted to resolve conflicts. Articles not meeting the eligibility criteria were excluded after a full-text assessment (Figure 1).

Following the formulation of our primary research question – “How does xylitol chewing gum affect the *S. mutans* count and its cariogenic properties?” – and utilizing multiple search engines, data extraction was carried out in three steps: identification, screening, and eligibility.

In the first step, articles were identified using keywords, resulting in 89 records: 58 from PubMed, 10 from Science Direct, 9 from Scopus, 8 from EBSCO, and 4 from Open Grey. Duplicates, totaling 19 articles, were removed both systematically and manually.

In the second step, seven reviewers screened the records by reviewing titles and abstracts according to the research question, leading to the exclusion of 11 articles.

The third step involved reading full-text articles to assess their eligibility. Based on the inclusion criteria – focusing on *S. mutans,* published post-1970, peer-reviewed, with appropriately reported outcomes, and excluding studies on other free-sugar

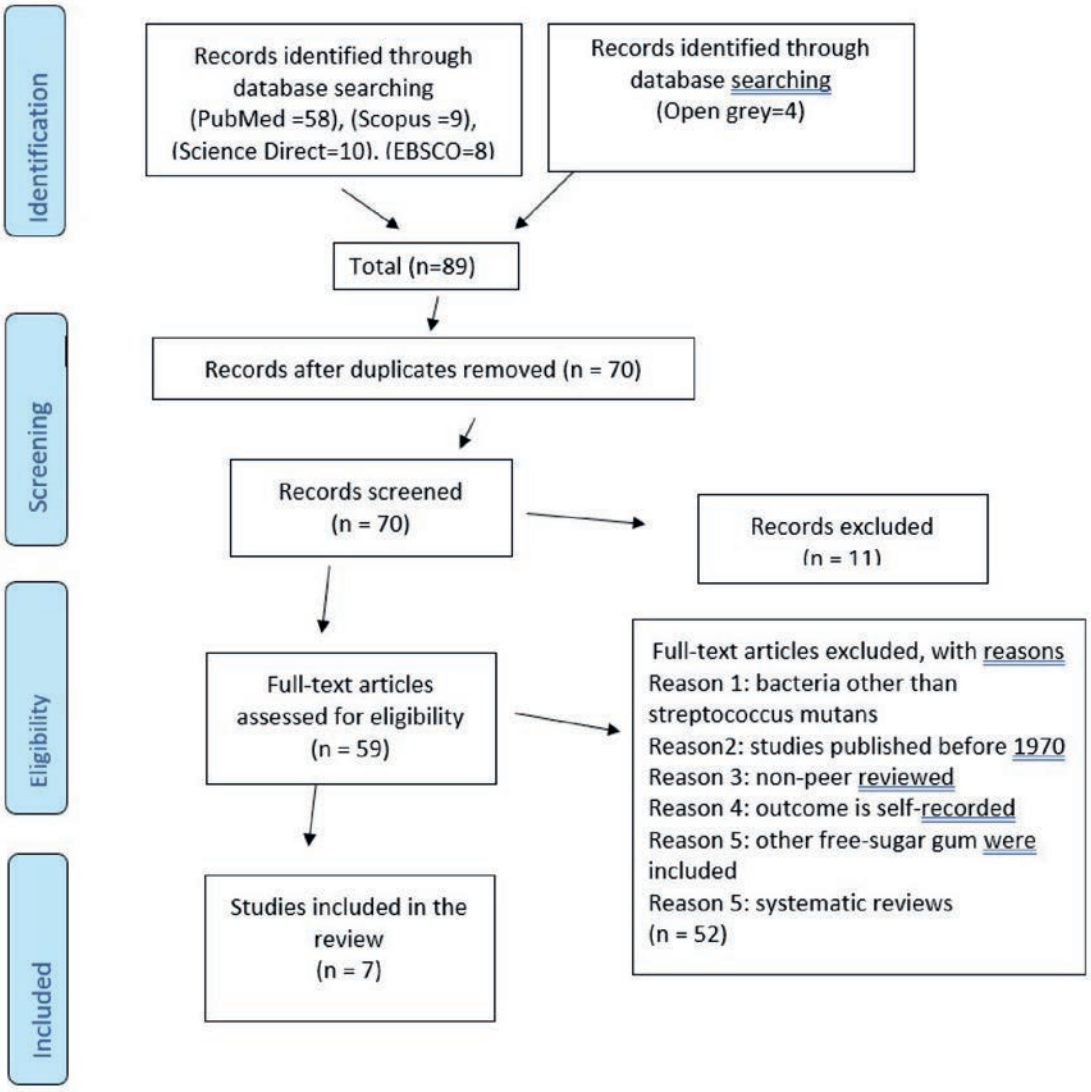


**FIGURE 1.** Flowchart of the examination plan

gums – 52 articles were excluded for reasons such as addressing bacteria other than *S. mutans*, being published before 1970, non-peer-reviewed status, self-reported outcomes, inclusion of other free-sugar gums, or being systematic reviews.

Ultimately, seven articles met the inclusion criteria and were included in the final analysis.

### Data Extraction and Data Items

Seven researchers developed and tested a list of outcomes to guide the data extraction process. The databases used for this review included PubMed, Scopus, Science Direct, and EBSCO, all accessed through the University of Sharjah library's discovery tool, which searches multiple online databases simultaneously.

In the initial search, research keywords were employed, with synonyms and alternative terms used to capture all relevant concepts. Boolean operators (AND, OR) were applied to refine the search: AND was used to narrow results to those containing all keywords, while OR was used to include synonyms. Quotation marks were used to search for specific phrases like "xylitol gum," "xylitol effectiveness," and "*S. mutans.*"

Data were extracted from the studies by the seven researchers, focusing on the following items:

- Intervention details: Information about the intervention, including the gum's specifications (components, concentrations), and recommended usage (frequency, duration).
- Participant characteristics: Data on age, socioeconomic status, sample size, diet, pre-existing conditions, risk factors, and dental hygiene.
- Study details: Author(s), title, journal, country of origin, year of publication, and trial design.
- Outcome measures: Detailed information on the number of participants in each group at baseline, those included in the analysis, number of withdrawals, follow-up duration, washout period, unit of randomization, and unit of analysis.

Any disagreements during the data extraction process were resolved through discussion.

### Studies Quality Assessment

The quality and validity of each study included in this review were assessed using the Critical Appraisals Skills Programme (CASP) checklist. This checklist provided a comprehensive evaluation across three main areas: Introduction, Methodology, and Results and Discussion. It included a series of questions designed to assess the strength of each study, with responses rated as "Yes" or "No."

Based on the CASP evaluation, studies were categorized into one of three evidence levels: weak, moderate, or strong. This categorization was determined by the percentage score of the checklist: 0-33% indicated weak evidence, 34-66% indicated moderate evidence, and 67-100% indicated strong evidence [Table 1].

**TABLE 1.** Assessment of quality of study of the eligible studies using CASP [Critical Appraisal Skills Program]

| Author, Year, country | Strength | Score % |
|---|---|---|
| Akgül, et al. 2019, Turkey [6] | Strong | 83% |
| Haresaku, et al. 2006, Japan [7] | Strong | 70% |
| Hanno, et al. 2011, Saudi Arabia [1] | Strong | 67% |
| Lee, et al. 2008, Republic of Korea [5] | Strong | 67% |
| Massoth, et al. 2006, California in USA [3] | Strong | 80% |
| Minh, et al. 2021, Vietnam [8] | Strong | 80% |
| Jaana T. 2002, Florida in USA [9] | Strong | 77% |

**TABLE 2.** Evidence table for the eligible studies

| Author, Year | Study Design | Population | N | Tools used for measuring the variables | Parameters of oral health | Main Findings | Comments |
|---|---|---|---|---|---|---|---|
| Akgül, et al. 2019 [6] | RCT | Adult patients (18-65 years) | 154 participants | Real-time PCR and ELISA | Gingival index, plaque index | - Gingival and plaque index scores were significantly decreased (P <0.001). - *S. mutans* expression was reduced about fivefold at 3-week, the salivary concentration of TNF-α, IL-6 and IL-8 were statistically declined | Several limitations and Further studies with larger samples are necessary |
| Haresaku, et al. 2006 [7] | RCT | Ground self-defence force 18 to 53 years (mean age 28.0) | 94 participants | modified mitis-Salivarius bacitracin medium | DMFT score, oral hygiene frequency and use of toothpaste | The XYL group showed a decrease in XYL levels in both saliva (p <0.05) and plaque (p <0.001) after 6 months. Conversely, in the MAL group, S. mutans levels in plaque increased significantly (p<0.001). No significant changes in S. mutans levels were observed in either saliva or plaque of the CR group or in the saliva of the MAL group. Notably, there were significant differences in the relative change of S. mutans levels in plaque between the XYL group and both the CR (p<0.05) and MAL groups (p<0.001) during the experimental period | Lack of blinding, Additional evaluation of xylitol gum use for prevention of dental caries is required |
| Hanno, et al. 2011 [1] | RCT | Children and mothers | 120 participants | (CRT) (Vivadent-Ivoclar, Lichenstein) bacteriological screening method | *S. mutans* level, Mean plaque scores, Mean dmft scores | The number of mothers and children in the experimental group with high streptococcus levels decreased significantly after the three-month period. Similarly, the control group mothers also showed a similar trend. However, only the experimental group children showed a statistically significant decrease in plaque scores. There were no statistically significant differences in the caries level between the children and mothers. | Longer follow-up and xylitol consumption needed |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Lee, et al. 2008 [5] | RCT | Adult women aged 24–35 years | 20 participants | Saliva sample was smeared onto Mitis Salivarius agar containing 0.2 U/ml of Bacitracin (MSB) and 15% sucrose | NA | There was a decrease in *S. mutans* counts for all time points compared to baseline in the control group, but these differences did not reach significance (p>0.025). In contrast, the xylitol group showed a significantly greater reduction in S. mutans counts than the control group at 6 and 12 months (p < 0.05) | Further studies with larger sample sizes are needed in order to obtain more reliable and consistent results regarding this findings |
| Massoth, et al. 2006 [3] | Before and after comparison | Second-grade students from the Los Angeles Unified School District | 91 participants | Monoclonal antibody-based detection method with fluorescence microscopy | Caries index levels | High-caries-risk children experienced a decrease in their levels of S. mutans in their saliva. However, children in the moderate caries index subgroup showed an increase in salivary *S. mutans* after chewing xylitol | Lack of blinding, Lack of a control group, Possibilities of sampling errors |
| Minh, et al. 2021 [8] | RCT | Patients age between (18-63 years) | 254 participants | Real-time PCR method | NA | After continuous use of xylitol chewing gum, it showed a decrease in the number of *S. mutans* in the saliva of participants, and the decrease was statistically significant | Further investigations should be done among different populations |
| Jaana T Autio 2002 [9] | RCT | Children between 3-5 years | 61 participants | Dentocult SM Strip mutans, transferred to a selective culture medium | dmft score, Caries prevalence, *S. mutans* scores | Greater decrease in the *Streptococcus mutans* levels (p<0.05) in xylitol group compared to control group. 75% children in the control group remained at the same values, 3% had an increase and 22% had reduced. While in the xylitol group, 42% didn't change, 10% increased, and 48% decreased | Further studies are required to assess the long-term acceptance, compliance, and effectiveness of incorporating gum chewing into school programs |

RCT (Randomized Clinical Trials); NA (not applicable)

## RESULTS

This systematic review included seven studies that focused on *S. mutans* counts as the primary outcome, as detailed in Table 2. Among these studies, four investigated adults, two focused on children, and one involved mother-child pairs. All studies utilized xylitol gum as the main intervention.

Table 2 summarizes the characteristics and findings of each study. Of the seven studies, six were randomized clinical trials (85.7%), and one was a before-and-after comparison (14.3%).

Sample sizes ranged from 60 to 254 participants, with one study involving only 20 participants, which may limit the reliability of its results. The duration of xylitol gum intervention varied from 3 weeks to 12 months. Most studies reported that xylitol gum effectively reduced *S. mutans* counts and thus potentially reduced caries risk. However, one study involving children with moderate caries risk found a non-significant increase in *S. mutans* levels. This study had several limitations, impacting the robustness of its findings.

In the study by Akgül et al., 154 participants were divided into xylitol and control groups to assess the short-term effects of xylitol in adults over 3 weeks. Using real-time PCR and ELISA, the study found a significant reduction in *S. mutans* levels by a factor of 5 (from 22 at baseline to 4 after three weeks) in the xylitol group (p<0.001), along with significant decreases in gingival and plaque index scores. Despite some limitations, this study suggests promising short-term benefits of xylitol.

Haresaku et al. evaluated the long-term effects of xylitol gum over 6 months with 94 participants from the Ground Self-Defense Force in Japan. Participants were divided into three groups: xylitol, maltitol, and control. Although no significant differences in DMFT scores were observed among the groups, *S. mutans* levels in saliva (p <0.05) and plaque (p <0.001) decreased significantly after 6 months. Specifically, saliva levels decreased from 5.8 ± 0.5 to 5.6 ± 0.7, and plaque levels decreased from 5.3 ± 0.8 to 4.8 ± 1.0. The study noted some limitations, such as the lack of blinding, which could affect the results.

## DISCUSSION

Xylitol, a sugar alcohol with a unique metabolic profile, shows considerable promise in reducing dental caries. Its inability to be metabolized by *S. mutans*, a bacterium known for its acidogenic properties and plaque formation, suggests that xylitol could effectively hinder the growth and colonization of this pathogen. By inhibiting *S. mutans* attachment to tooth surfaces and reducing caries incidence, xylitol has emerged as a potent preventive agent in dental care. This review supports the efficacy of xylitol gum in diminishing *S. mutans* counts and suggests its potential as an adjunctive preventive measure in dental hygiene [5,10-14].

The studies included in this review spanned diverse populations, including children, adults, and mother-child pairs, and varied in duration from 3 weeks to 12 months. Most studies (six out of seven) were randomized clinical trials, which strengthens the validity of their findings. The evidence consistently indicates that xylitol gum reduces *S. mutans* levels in saliva and plaque, thereby potentially decreasing caries risk [15-20].

Several studies provided significant insights:

Akgül et al. [6] demonstrated a substantial short-term reduction in *S. mutans* (5-fold decrease) after 3 weeks of xylitol gum use. The study also noted improvements in gingival and plaque indices, highlighting the potential for xylitol to offer both immediate and measurable benefits. Haresaku et al. [7] assessed the long-term impact of xylitol gum over 6 months. Although DMFT scores showed no significant differences, notable reductions in *S. mutans* levels in both saliva and plaque were observed, underscoring the gum's efficacy in managing bacterial populations over time. Hanno et al. [1] found significant reductions in *S. mutans* levels in children but less consistent results in mothers. The study also highlighted the influence of xylitol on plaque scores and caries risk, though it indicated that some participants found the gum less acceptable. Lee et al. [5] observed morphological changes in *S. mutans* colonies after a year of xylitol use, including smaller colony sizes and reduced adherence, which supports xylitol's role in altering bacterial characteristics and reducing pathogenic potential. Massoth et al. [3] showed a substantial decrease in *S. mutans* among high caries risk students using xylitol gum for 21 days. However, the study faced limitations such as sampling errors and lack of a control group, which might affect its reliability. Minh et al. [8] found significant reductions in *S. mutans* in a large-scale study with adults chewing xylitol gum four times a day for 4 weeks, reinforcing the gum's effectiveness in a broader population. Autio et al.[9] observed a significant reduction in *S. mutans* scores in preschool children after three weeks of using xylitol gum, demonstrating its effectiveness in a younger demographic.

Despite the positive outcomes, limitations were noted across studies, including small sample sizes, varying intervention durations, and methodological differences. These limitations underscore the need for further research with larger sample sizes, longer follow-ups, and more rigorous control conditions to solidify xylitol's role in caries prevention [21-26].

In addition, xylitol's benefits extend beyond *S. mutans* reduction. It has been shown to enhance remineralization of carious enamel and inhibit demineralization, offering broader protective effects. The ability of xylitol to maintain its efficacy even after discontinuation of use suggests it could play a crucial role in long-term caries management [27-30].

## CONCLUSION

The systematic review concludes that xylitol chewing gum significantly impacts *S. mutans* levels, with many studies demonstrating reduced counts and improved dental indices. Xylitol gum effectively inhibits bacterial growth, reduces plaque, and alters bacterial morphology, contributing to its caries-preventive properties. While most studies show beneficial outcomes, the presence of certain limitations highlights the need for further research. Future studies should focus on larger sample sizes, extended intervention periods, and diverse populations to better understand and confirm xylitol's role in dental caries prevention.

### Ethical Approval

As this study is a systematic review of existing published literature, it does not require ethical approval.

The research relies on secondary data obtained from studies that have already been conducted and published, and does not involve direct interactions with human subjects.

*Conflict of interest:* none declared

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