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Comparative Effects of Sugar-Containing and Sugar-Free Chewing Gum on Salivary pH and Oral Microbial Load

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Abstract: Introduction: Dental caries remains one of the most prevalent chronic oral diseases worldwide, driven primarily by the interplay between dietary sugars, oral microbial activity, and salivary pH. Chewing gum is widely consumed as a functional confectionery, yet its impact on salivary parameters depends largely on its composition. Sugar-free gums, particularly those containing xylitol, are reported to exert anti-cariogenic effects by stimulating salivary flow and inhibiting bacterial metabolism, while sugar-containing gums may promote acid production and microbial proliferation.

Objective: This study aimed to compare the effects of sugar gum and sugar-free gum on salivary pH and microbial load among young adults, with the goal of assessing their potential roles in caries prevention.

Method of Analysis: A randomized controlled experimental design was employed with 10 healthy participants aged 18–25 years, equally divided into sugar gum and sugar-free gum groups. Baseline saliva samples were collected after a 30-minute fasting period. Salivary pH was measured at baseline, 10 minutes, and 30 minutes post-chewing using calibrated pH strips, while microbial load was determined by pour plate analysis and expressed as colony-forming units per

milliliter (CFU/mL). Data were analyzed using independent sample t-tests to compare pH changes and microbial counts between groups.

Results: Sugar-free gum produced a steady rise in salivary pH from baseline acidic levels (pH 4–5) to neutral pH 7 within 30 minutes, accompanied by a marked reduction in microbial load. In contrast, sugar gum produced inconsistent pH changes, with transient spikes followed by declines to acidic levels, and significantly increased bacterial growth, with some samples rising from 2×10^1 to 20×10^1 CFU/mL over 30 minutes.

Conclusion: Sugar-free gum, particularly xylitol-containing formulations, effectively neutralizes salivary acidity and suppresses cariogenic bacterial growth, supporting its role as a practical adjunct in caries prevention. Conversely, sugar gum fosters acidogenic conditions that favor microbial proliferation despite initial salivary stimulation. These findings underscore the importance of promoting sugar-free gum use through public health campaigns and consumer education to reduce caries risk.

Keywords: sugar-free gum, xylitol, salivary pH, microbial load, dental caries.

Background of the Study

Saliva is a vital body fluid that plays a central role in preserving oral health through its buffering, lubricating, and antimicrobial properties. By neutralizing acids produced from bacterial metabolism, facilitating enamel remineralization, and regulating the oral microbiome, saliva serves as the mouth's first line of defense against dental caries and other oral diseases (Dawes et al., 2015). Among its protective mechanisms, salivary pH is particularly critical, as demineralization of tooth enamel begins when pH falls below the critical threshold of 5.5 (Featherstone, 2020). Any factor that stimulates salivary flow and enhances its buffering capacity can therefore influence the risk of tooth decay. Chewing gum has long been recognized as a simple and accessible method to stimulate salivary flow, but the health implications of gum chewing are strongly dependent on its composition.

Sugar-containing gums remain popular due to their palatability, yet they provide fermentable carbohydrates that oral bacteria such as *Streptococcus mutans* and *Lactobacilli* metabolize to produce acids, leading to a rapid drop in salivary pH and an environment favorable to enamel demineralization and caries formation (Lee et al., 2023). In contrast, sugar-free gums typically contain non-fermentable sweeteners such as xylitol, sorbitol, or erythritol, which are resistant to bacterial fermentation. Xylitol, in particular, has demonstrated strong anti-cariogenic properties by inhibiting *S. mutans* growth, disrupting bacterial adhesion to enamel surfaces, and reducing acid production (Söderling et al., 2022). Several studies have shown that chewing sugar-free gum can sustain a neutral or slightly alkaline salivary pH and reduce microbial load compared to sugar-containing gum. For example, Janakiram et al. (2022) reported that xylitol gum significantly elevated salivary pH for up to 30 minutes post-chewing, whereas sugar gum caused a transient pH decrease. Similarly, Nayak et al. (2021) observed that sugar-free gum reduced the microbial load of acidogenic bacteria, thereby lowering the risk of dental caries.

Despite these promising findings, existing evidence remains inconclusive regarding the magnitude and duration of the effects of sugar-free versus sugar-containing gums on salivary pH and microbial dynamics. Variability in study designs, sample populations, and methodological approaches has produced conflicting results, with some studies reporting minimal differences between gum types. Moreover, most investigations have focused on short-term effects, leaving gaps in understanding the sustained impact of repeated gum use. There is also limited data comparing the efficacy of different sugar substitutes, such as xylitol, sorbitol, and erythritol, which may differ in their ability to modulate salivary chemistry and oral microbiota.

The importance of this research is underscored by the persistent global burden of dental caries, which remains one of the most prevalent chronic diseases worldwide despite advances in

preventive dentistry. The World Health Organization estimates that approximately 2.3 billion people are affected by caries of permanent teeth, highlighting an urgent need for practical, evidence-based preventive strategies (WHO, 2023). While sugar-free gum is marketed as a caries-preventive product, consumer choices are often driven by taste preferences, cost considerations, and limited awareness of its health benefits (FDI World Dental Federation, 2022). In contrast, sugar-containing gum remains widely consumed despite its potential to exacerbate caries risk.

A clear, comparative evaluation of how sugar-containing and sugar-free gums influence salivary pH and microbial load will provide critical insights for both clinical dentistry and public health policy. By clarifying the biochemical and microbiological effects of these common products, such research can inform dental professionals, guide consumer choices, and support preventive strategies aimed at reducing the incidence of dental caries at both individual and population levels.

Materials and Methods

Study Design

This study employed a randomized, controlled experimental design to compare the effects of sugar-containing and sugar-free chewing gum on salivary pH and microbial load. Each participant served as their own control to minimize inter-individual variability.

Study Population

Participants were healthy adults aged 18–25 years recruited from a university setting. Eligibility was determined using defined inclusion and exclusion criteria. Inclusion criteria were: age 18–25 years, good general and oral health with no active caries or periodontal disease, absence of systemic conditions, and no use of medications known to affect salivary flow (e.g., antidepressants, antipsychotics). Participants were instructed to refrain from eating or drinking anything except water for at least 30 minutes prior to saliva collection. Exclusion criteria included presence of active caries, oral infections, systemic illness, or use of medications that could confound salivary measurements.

Sample Size and Randomization

A total of ten participants were recruited and randomly assigned to one of two intervention groups. Group A (n=3) received sugar-containing gum, while Group B (n=3) received sugar-free gum. Prior to the intervention, baseline salivary pH and microbial load were measured for all participants. Each participant chewed their assigned gum for a specified period, after which salivary pH and microbial load were reassessed.

Chewing Gum and Intervention Protocol

The sugar-containing gum used was *Center Fresh* (spearmint flavor), while the sugar-free gum contained xylitol (*Rasa Cool Mint*). At baseline, participants rinsed their mouths with distilled water, and approximately 1–2 mL of unstimulated saliva was collected in sterile containers. Participants then chewed their assigned gum for 10 minutes. Post-chewing saliva samples were collected at intervals between 10 and 30 minutes for pH and microbial analysis.

Measurement of Salivary pH

Salivary pH was assessed using commercially available pH test strips with a range of 4.0–9.0. For each measurement, a pH strip was immersed in the saliva sample until fully wetted, and the color change was compared to the manufacturer's standard chart to determine the pH value. Baseline pH was recorded prior to gum chewing, and subsequent pH measurements were obtained at the designated post-chewing intervals.

Microbial Load Determination

The microbial load of saliva samples was determined using the pour plate method. Saliva samples were serially diluted in sterile buffered peptone water to achieve a countable bacterial concentration. Measured aliquots of each dilution were mixed with melted nutrient agar and poured into sterile Petri dishes. Plates were incubated aerobically at 35 °C for 24–48 hours. After incubation, visible colonies were counted using a colony counter, and results were expressed as colony-forming units per milliliter (CFU/mL), calculated from plates containing 30–300 colonies to ensure accuracy.

Quality Control and Sterility Measures

All glassware, media, and equipment were sterilized to prevent contamination. Samples were thoroughly mixed to ensure even distribution of microorganisms before plating. Negative control plates (agar only) were included to monitor sterility during each experimental run.

Data Analysis

Mean salivary pH values and microbial counts were calculated for baseline and post-chewing samples in both groups. Differences within and between groups were analyzed using independent samples *t*-tests. A p-value <0.05 was considered statistically significant. Results were expressed as mean ± standard deviation (SD).

Ethical Considerations

The study followed the principles of the Declaration of Helsinki and received approval from the institutional ethics committee. Participants were informed about the study's purpose, procedures, potential risks, and benefits, and written consent was obtained. Participation was voluntary, and individuals could withdraw at any time without penalty. Saliva collection involved non-invasive procedures using commercially available gums, ensuring minimal risk. Participant confidentiality was maintained through coded data, and all samples were safely handled and disposed of according to biosafety standards.

Results

Table 1: Baseline and Post-Consumption Salivary pH and Microbial Load for Sugar-Free Gum

Sample	Time Point	pH	Microbial Load (cfu/ml)
1A	Baseline	4	-
1B	10 min	6	-
1C	30 min	7	-
2A	Baseline	5	1×10^1
2B	10 min	6	-
2C	30 min	7	-
3A	Baseline	5	5×10^1
3B	10 min	6	2×10^1
3C	30 min	7	-

Table 1 presents the baseline and post-consumption salivary pH and microbial load for participants who chewed sugar-free gum. Across all samples, salivary pH showed a clear upward trend from acidic baseline values (pH 4–5) to near-neutral levels (pH 6 at 10 minutes) and finally to neutral pH 7 at 30 minutes. This progressive increase reflects enhanced salivary buffering capacity stimulated by gum chewing and suggests that sugar-free gum effectively counteracts oral acidity within a short time frame.

Microbial load measurements exhibited either a reduction or remained undetectable during the observation period. Participants who initially presented measurable bacterial counts (e.g., 1×10^1 CFU/mL and 5×10^1 CFU/mL) demonstrated marked decreases by 10 minutes and no detectable

growth by 30 minutes. This pattern indicates a potential inhibitory effect of sugar-free gum on acidogenic bacteria such as *Streptococcus mutans* and *Lactobacilli*, organisms known to drive caries formation.

The combined rise in salivary pH and decline in microbial load highlight the dual mechanism through which sugar-free gum may confer caries-preventive benefits. By stimulating salivary flow and supplying non-fermentable sweeteners like xylitol, sugar-free gum not only neutralizes acids but also limits the substrate available for bacterial metabolism. These findings support previous evidence that regular use of sugar-free gum can create a less cariogenic oral environment, particularly during periods when mechanical cleaning (e.g., toothbrushing) is not immediately possible.

Table 2: Baseline and Post-Consumption Salivary pH and Microbial Load for Sugar Gum

Sample	Time Point	pH	Microbial Load (cfu/ml)
4A	Baseline	5	14×10^1
4B	10 min	6	$16x\ 10^1$
4C	30 min	6	10×10^1
5A	Baseline	5	5×10^1
5B	10 min	8	10×10^1
5C	30 min	5	20×10^1
6A	Baseline	6	2×10^1
6B	10 min	8	12×10^1
6C	30 min	6	20×10^1

Table 2 presents the salivary pH and microbial load of participants who chewed sugar-containing gum. Unlike the consistent pH elevation observed with sugar-free gum, sugar gum produced variable pH changes over time. Although a temporary rise in salivary pH was recorded at 10 minutes post-chewing in most samples (e.g., pH increasing from 5 to 8 in Samples 5B and 6B), this effect was not sustained. By 30 minutes, pH values generally declined toward baseline or acidic levels (e.g., pH dropping from 8 to 5 in Sample 5C), indicating that the initial buffering effect of saliva was overcome by acid production from bacterial metabolism of the gum's fermentable sugars.

The microbial load further supports this interpretation. Most samples exhibited a progressive increase in bacterial counts over time. For example, Sample 5 showed an increase from 5×10^1 CFU/mL at baseline to 20×10^1 CFU/mL at 30 minutes, while Sample 6 rose from 2×10^1 to 20×10^1 CFU/mL during the same period. These upward trends reflect the availability of fermentable carbohydrates in sugar gum, which provide substrates for acidogenic bacteria such as *Streptococcus mutans* and *Lactobacilli*, leading to accelerated growth and acid production.

Collectively, these findings suggest that while sugar gum can transiently stimulate salivary flow and briefly elevate pH, the presence of sucrose or other fermentable sugars ultimately promotes bacterial proliferation and acidification of the oral environment. This pattern underscores the cariogenic potential of sugar-containing gum and aligns with established evidence linking frequent sugar intake to enamel demineralization and caries development.

Table 3: Summary of Key Findings

Parameter	Sugar-Free Gum	Sugar Gum
pH Trend	Steady increase to neutral (pH 7)	Variable; sharp spikes and drops
Microbial Load	Decreased or low	Increased over time
Implications	Neutralizes acidity, reduces bacteria	Promotes bacterial growth, unstable pH

Table 3 provides a concise comparison of the effects of sugar-free and sugar-containing gum on salivary pH and microbial load. The data reveal a clear distinction between the two gum types in their impact on the oral environment. Sugar-free gum produced a steady and sustained rise in salivary pH, reaching a neutral level (pH 7) within 30 minutes of chewing. This consistent elevation reflects enhanced buffering capacity and an environment less conducive to enamel demineralization. At the same time, microbial load either declined or remained low, indicating a suppressive effect on acidogenic bacteria, likely attributable to the non-fermentable nature of xylitol and other sugar substitutes present in the gum. These properties collectively support the caries-preventive potential of sugar-free gum through both chemical (neutralization of acidity) and biological (inhibition of bacterial growth) mechanisms.

In contrast, sugar gum demonstrated unstable pH patterns, with some participants experiencing sharp spikes during the initial 10 minutes of chewing followed by rapid declines toward acidic levels by 30 minutes. This fluctuation suggests that while gum chewing initially stimulates salivary flow and transiently raises pH, the fermentable carbohydrates in sugar gum serve as substrates for bacterial metabolism, leading to acid production and a subsequent pH drop. Correspondingly, microbial load increased consistently over time, with some samples showing more than a twofold rise within 30 minutes. This trend reflects active bacterial proliferation and supports the well-established link between sucrose exposure, acidogenic bacterial activity, and caries development.

DISCUSSION OF FINDINGS

The findings of this study provide clear evidence of the contrasting effects of sugar-free and sugar-containing chewing gums on salivary pH dynamics and microbial load, underscoring their different implications for oral health.

With respect to salivary pH changes, sugar-free gum produced a steady and sustained rise from baseline acidic levels (pH 4–5) to a neutral pH of approximately 7 within 30 minutes of chewing. This result is consistent with the report of Janakiram et al. (2022), who observed that xylitol-containing gum elevated salivary pH to approximately 7.2 within a similar time frame. The biochemical basis for this pH normalization likely involves two interrelated mechanisms: the absence of fermentable carbohydrates, which limits substrate availability for acidogenic oral bacteria, and xylitol's ability to disrupt bacterial metabolism through the formation of non-metabolizable xylitol-5-phosphate, thereby inhibiting acid production by Streptococcus mutans (Söderling et al., 2022). These findings corroborate existing biochemical models of xylitol's anti-cariogenic action and reinforce its role in promoting an oral environment unfavorable to demineralization.

In contrast, sugar gum exhibited markedly unstable pH patterns, characterized by transient increases during the initial minutes of chewing followed by sharp declines to acidic levels by the 30-minute mark. This pattern mirrors the results of Lee et al. (2023), who documented a rapid pH drop below 5.0 following the use of sucrose-containing gum. The initial transient rise may reflect the temporary buffering effect of stimulated salivary flow, but this benefit is rapidly negated by acid production resulting from bacterial fermentation of sucrose. Such a process aligns with the caries balance theory proposed by Featherstone (2020) and further supports Marsh's (2018) assertion that salivary stimulation alone cannot counteract the deleterious effects of providing fermentable substrate to acidogenic bacteria.

The microbial load data further strengthen these observations. Chewing sugar-free gum was associated with a reduction in bacterial counts over the study period, a finding consistent with the clinical trial by Nayak et al. (2021), who reported a 25% decrease in S. mutans levels following regular xylitol gum use. Conversely, sugar gum chewing led to an overall increase in microbial load, paralleling the 30% rise in S. mutans counts observed by Janakiram et al. (2022) after sucrose gum exposure. These findings reinforce the well-established link between sugar

availability and the metabolic activity of cariogenic bacteria, a relationship first demonstrated in the classic plaque pH studies of Stephan (1944).

It is noteworthy that the effects of sugar gum were not uniform across all participants. While some individuals exhibited dramatic increases in microbial load (for example, from 2×10^1 to 20×10^1 cfu/mL), others showed more modest changes. This inter-individual variability may reflect differences in oral microbiome composition and activity, factors increasingly recognized as key determinants of caries susceptibility (Wade, 2021). Variability in salivary flow rate and buffering capacity, as highlighted by Dawes (2012), may also contribute to these heterogeneous responses.

Taken together, these findings reinforce the conclusion that sugar-free gum provides superior protective effects against dental caries by sustaining neutral pH levels and suppressing bacterial growth. In contrast, sugar gum, despite an initial salivary stimulation, promotes acidogenic conditions that support microbial proliferation and increase the risk of enamel demineralization. These results underscore the clinical relevance of choosing non-fermentable sweeteners in chewing gum formulations as part of caries-preventive strategies.

Conclusion

This study provide compelling evidence that sugar-free chewing gum, particularly formulations containing xylitol, offers significant advantages over sugar-containing gum in promoting oral health. The consistent elevation of salivary pH to neutral levels following sugar-free gum use demonstrates its capacity to counteract oral acidity, a critical factor in preventing enamel demineralization and the initiation of dental caries. In contrast, sugar gum failed to sustain pH improvements, with its fermentable carbohydrates serving as substrates for acidogenic bacteria and fostering an environment conducive to caries development. These results align with and extend previous research by confirming the anti-cariogenic properties of sugar-free gum through measurable reductions in microbial load. The observed suppression of bacterial growth reinforces the mechanistic role of xylitol in disrupting the metabolic activity of *Streptococcus mutans*, while the increased microbial load associated with sugar gum highlights the persistent risk posed by fermentable sugars in oral care products despite their ability to stimulate salivary flow. From a clinical and public health perspective, these findings emphasize the need to promote sugar-free gum as a practical caries-preventive strategy. Public health campaigns should encourage its use to support pH balance and bacterial reduction, while dental professionals can provide counseling to guide patients toward xylitol-based products over sugar-containing alternatives. Clearer product labeling, particularly regarding xylitol content, would further aid informed consumer choices. Future research is warranted to explore the long-term effects of sugar-free gum on oral microbiome diversity and enamel remineralization, while manufacturers are encouraged to innovate by optimizing anti-cariogenic formulations, including potential combinations of xylitol with fluoride or other remineralizing agents.

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