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# Probiotics and Their Therapeutic Applications in Dental Plaque Management: An Overview of Preclinical and Clinical Evidence

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**A B S T R A C T**

**Objective:** Dental plaque is a complex microbial biofilm recognized as a major etiological factor in the development of dental caries, gingivitis, and periodontal diseases. Probiotics have recently gained attention as a promising preventive and therapeutic strategy due to their ability to modulate the oral microbiome, inhibit pathogenic microorganisms, and interfere with biofilm formation. This review aimed to identify and evaluate probiotic strains with potential applications in the prevention and management of dental plaque.

**Methods:** In this narrative review, relevant studies published between 2010 and 2026 were retrieved from major scientific databases, including PubMed, Scopus, SID, ISC, and Google Scholar. Eligible studies were selected based on their relevance to the preventive and therapeutic roles of probiotics in controlling dental plaque formation and maintaining oral microbial homeostasis.

**Results:** The reviewed evidence suggests that probiotics may contribute to dental plaque management by reducing biofilm formation and limiting microbial colonization on tooth surfaces. Several probiotic strains, particularly those belonging to the genera Lactobacillus and Bifidobacterium, have demonstrated the ability to inhibit oral pathogens and promote a more balanced microbial environment within the oral cavity. Clinical studies have reported improvements in plaque indices and gingival inflammatory parameters following probiotic supplementation in selected populations. However, the effectiveness of probiotics appears to depend on strain specificity, dosage, treatment duration, and formulation characteristics. Preclinical investigations have further elucidated potential mechanisms of action, including inhibition of bacterial adhesion, disruption of biofilm maturation, production of antimicrobial compounds, and competitive exclusion of pathogenic species. Nevertheless, substantial heterogeneity among studies has contributed to inconsistent findings regarding the overall efficacy of probiotics. Collectively, current evidence indicates that probiotics may represent a promising complementary approach for the prevention and control of dental plaque.

**Conclusion:** By modulating the oral microbial ecosystem and suppressing pathogenic bacteria, probiotics may serve as an effective adjunctive strategy for preventing dental plaque accumulation and improving oral health outcomes. Considering the variability among probiotic strains and differences in clinical responses, further well-designed randomized clinical trials are warranted to determine optimal strains, dosages, treatment durations, and suitable probiotic formulations.

**Keywords:** Oral cavity, Dental health, Oral diseases, Probiotics, Oral microbiota, Modern therapeutic approaches

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## Introduction

Oral and dental diseases and disorders are among the most common health problems [1-3] and may be associated with conditions such as dental caries, periodontal diseases, microbial infections, and oral mucosal disorders. In addition to causing pain and impairing chewing and speech, these conditions can adversely affect overall health and quality of life if left untreated.

Dental plaque is recognized as one of the most important contributing factors in the initiation and progression of oral diseases [2]. It is a complex, highly organized microbial biofilm that develops on tooth surfaces and adjacent oral tissues [2,3]. Dental plaque comprises diverse bacterial communities embedded within an extracellular polymeric matrix and continuously interacts with the surrounding oral environment and host immune responses [3,4]. The accumulation and maturation of this biofilm can disrupt oral microbial homeostasis, facilitating the colonization and proliferation of pathogenic microorganisms [4,5].

The development and progression of dental plaque are influenced by multiple factors, including the composition of the oral microbiome, salivary properties, tooth surface characteristics, dietary patterns, and oral hygiene practices [4,5]. Frequent intake of fermentable carbohydrates, inadequate oral hygiene, xerostomia, tobacco consumption, dental malocclusion, and the presence of orthodontic appliances may further accelerate plaque accumulation. Under these conditions, alterations in microbial composition and the establishment of oral dysbiosis play critical roles in disease initiation and progression [5,6]. From a pathophysiological perspective, dental plaque contributes to the development of dental caries through bacterial fermentation and acid production, resulting in the establishment of an acidic microenvironment [7]. The reduction in local pH promotes enamel demineralization and facilitates the progression of carious lesions [8]. Similarly, in gingival and periodontal diseases, plaque accumulation stimulates host inflammatory responses. Persistent inflammation may subsequently lead to periodontal tissue destruction, alveolar bone resorption, tooth mobility, and ultimately tooth loss [8].

Uncontrolled dental plaque accumulation is associated with numerous oral complications, including dental caries, gingivitis, gingival bleeding, halitosis, calculus formation, and periodontal diseases [9]. Therefore, effective plaque control is considered a cornerstone of preventive dentistry and plays an essential role in preserving oral health [10].

Current strategies for dental plaque management primarily rely on mechanical approaches, including tooth brushing, flossing, and professional dental cleaning, along with chemical control methods such as antimicrobial mouth rinses [11]. Chlorhexidine remains one of the most widely used and effective chemical agents for inhibiting plaque formation and controlling gingival inflammation [12]. However, long-term chlorhexidine use may cause several adverse effects, including tooth discoloration, taste disturbances, increased calculus accumulation, and irritation of oral mucosal tissues. These limitations have stimulated growing interest in alternative, safe, and biologically based preventive approaches [13].

Probiotics have emerged as a promising strategy for oral health promotion due to their potential capacity to modulate the oral microbiome, compete with pathogenic microorganisms, inhibit bacterial adhesion, and interfere with biofilm formation [14]. Several probiotic strains, particularly those belonging to the genera *Lactobacillus* and *Bifidobacterium*, have demonstrated beneficial effects in both preclinical and clinical studies [15]. However, probiotic efficacy is highly dependent on various factors, including strain-specific characteristics, dosage, administration period, delivery formulation, and host-related factors [14,15].

Considering the variability and inconsistent outcomes reported among previous investigations, a comprehensive assessment of available preclinical and clinical evidence is necessary to clarify the therapeutic potential of probiotics in dental plaque management. Therefore, this review aimed to evaluate the mechanisms of action, effective probiotic strains, and therapeutic applications of probiotics for the prevention and control of dental plaque

## Methods

This narrative review was undertaken to identify, evaluate, and synthesize the available evidence on the role of probiotics in the prevention and management of dental plaque. A literature search was conducted across major international databases, including PubMed, Scopus, Web of Science, Embase, and the Cochrane Library, as well as Persian databases, including SID and Magiran, covering publications from January 2010 to December 2025.

The search strategy incorporated a combination of free-text keywords and Medical Subject Headings (MeSH) terms relevant to the research topic. The principal search terms included *probiotics, probiotic, dental plaque, dental biofilm, oral biofilm, oral microbiota, oral microbiome, dental caries, gingivitis, periodontal disease, Lactobacillus,* and *Bifidobacterium*. These terms were combined using the Boolean operators AND and OR to broaden and refine the retrieval of relevant literature.

Preclinical, in vitro, animal, and clinical studies investigating the effects of probiotics on dental plaque or biofilm formation, microbial burden, gingival inflammation, or other indicators of oral health were considered for inclusion. Studies that did not address the objectives of the review were excluded, as were duplicate publications, case reports, letters to the editor, conference abstracts, studies for which the full text was unavailable, and articles providing insufficient information on the probiotic intervention or relevant outcomes.

Following the initial search, duplicate records were identified and removed. The retrieved articles were then screened based on their titles and abstracts, followed by full-text assessment of potentially relevant studies. Studies meeting the eligibility criteria and providing relevant evidence on the role of probiotics in dental plaque management were subsequently included in the qualitative synthesis.

Data extracted from the selected studies included the first author, publication year, country, study design, study population or experimental model, probiotic species and strains, dosage and route of administration, intervention duration, comparator or control group, plaque and biofilm assessment methods, microbiological and clinical outcomes, and reported adverse effects. Given the narrative nature of the review and the substantial heterogeneity among the included studies with respect to probiotic strains, administration protocols, study populations, experimental models, and outcome measures, the findings were synthesized qualitatively and compared descriptively. Particular emphasis was placed on identifying probiotic strains with potential efficacy, elucidating their proposed mechanisms of action, and critically evaluating the preclinical and clinical evidence supporting the use of probiotics as a complementary strategy for the prevention and management of dental plaque.

## Results

The available evidence suggests that probiotics, particularly selected strains of *Lactobacillus* and *Bifidobacterium*, may contribute to the reduction of dental plaque accumulation and gingival inflammation through mechanisms such as inhibition of bacterial adhesion and interference with biofilm formation. However, the magnitude and consistency of these effects varied considerably according to the probiotic strain, dosage, duration of administration, and formulation. Overall, probiotics show promising potential as an adjunctive strategy for dental plaque control and the promotion of oral health. Nevertheless, further well-designed and adequately powered clinical trials are warranted to establish their efficacy and determine the optimal probiotic strains, dosages, treatment durations, and formulations.

Findings from in vitro studies indicated that probiotics, particularly selected strains of *Lactobacillus* and *Bifidobacterium*, may inhibit the growth of oral pathogens and reduce bacterial adhesion and dental biofilm formation. The magnitude of these effects varied considerably among probiotic strains and appeared to be associated with strain-specific antimicrobial properties and interactions with the oral microbial environment (Table 1).

**Table 1. In Vitro and Laboratory Studies Evaluating the Effects of Probiotics on Dental Plaque**

| Reference | Study design | Intervention | Primary outcome | Key findings |
|---|---|---|---|---|
| Zambori et al., 2016 | In vitro | *L. casei* DG; LA-5 + BB-12 | Plaque-associated bacteria | *L. casei* DG demonstrated greater bactericidal activity against plaque-associated bacteria than the other probiotic preparations evaluated [16]. |
| Keller & Twetman, 2012 | In vitro | *L. reuteri* DSM 17938; *L. plantarum* 299v | Plaque acidogenicity | Acid production varied in a strain-dependent manner; probiotic exposure did not increase plaque acidogenicity [17]. |
| Tahmourespour & Kermanshahi, 2011 | In vitro | *L. acidophilus* DSM 20079 | Streptococcal adhesion | Probiotic exposure reduced bacterial adhesion, particularly among *mutans streptococci [18]*. |
| Choksket et al., 2023 | In vitro | Four *Lactobacillus* strains | Lactic acid production, pH, and biofilm formation | Considerable strain-dependent differences were observed in probiotic characteristics, including effects on lactic acid production, pH, and biofilm formation [19]. |

Animal studies suggest that probiotics may reduce *Streptococcus mutans* colonization, inhibit dental biofilm formation, decrease extracellular polymeric substance production, and modulate the microbial composition of dental plaque. Collectively, these findings provide preclinical evidence supporting the potential role of probiotics in controlling dental plaque accumulation and caries-associated processes (Table 2).

**Table 2. Animal and In Vivo Studies Evaluating the Effects of Probiotics on Dental Plaque and Caries**

| Reference | Study design / Model | Intervention | Primary outcome | Key findings |
|---|---|---|---|---|
| Zhang et al., 2024 | In vitro and rat model | Four-strain *Lactobacillus* mixture | *S. mutans*, biofilm formation, and dental caries | The intervention inhibited bacterial growth and biofilm formation and reduced *S. mutans* levels [20]. |
| Guo et al., 2023 | Animal and laboratory models | *L. paracasei* ET-22 | Dental caries and biofilm formation | The intervention inhibited biofilm and extracellular polymeric substance (EPS) production and modulated the microbial composition of dental plaque [21]. |
| Sadighnia et al., 2023 | Canine model | Dextranase + *E. faecium* | Bacterial levels and *hmuY* expression | The combined intervention reduced bacterial levels and *hmuY* expression [22]. |
| Campus et al., 2025 | In vitro, ex vivo, and in vivo models | *L. brevis* CD2 | Sugar fermentation and plaque acidification | The intervention reduced sugar fermentation and plaque acidification [23]. |

Randomized clinical trials have generally indicated that probiotic interventions may reduce dental plaque accumulation, gingival inflammation, and the levels of selected pathogenic oral bacteria. However, the magnitude and consistency of these effects varied considerably across studies and appeared to depend on several factors, including probiotic strain, dosage, duration of administration, and product formulation (Table 3).

**Table 3. Randomized Controlled Trials Evaluating the Effects of Probiotics on Dental Plaque and Oral Health**

| Reference | Study design / Population | Intervention | Primary outcome | Key findings |
|---|---|---|---|---|
| Alhallak et al., 2022 | RCT | Probiotic mouthwash | Plaque index (PI) | Greater reductions in plaque accumulation were observed on days 14 and 30 [24]. |
| Alanzi et al., 2018 | RCT; adolescents | LGG + BB-12 | Gingival index (GI) and periodontal pathogens | GI scores and levels of selected periodontal pathogens were reduced [25]. |
| Karuppaiah et al., 2013 | RCT; children | Probiotic yogurt | PI and GI | PI was significantly reduced, whereas the improvement in GI was not statistically significant [26]. |
| Dadgar et al., 2021 | RCT | *L. plantarum* versus fluoride | *S. mutans* | *L. plantarum* did not produce a significant reduction in *S. mutans*, whereas fluoride demonstrated a significant effect [27]. |
| Ratna Sudha et al., 2020 | Double-blind RCT | *B. coagulans* Unique IS2 | *Mutans streptococci* and *Lactobacillus* spp. | Both bacterial groups were reduced following probiotic administration [28]. |
| Jose et al., 2013 | RCT / clinical study | Probiotic yogurt and probiotic toothpaste | *S. mutans* | Both interventions demonstrated beneficial effects against *S. mutans [29]*. |
| Shah et al., 2019 | RCT; orthodontic patients | Probiotic mouthwash and chlorhexidine | PI and GI | Both interventions reduced PI, with effects observed following treatment [30]. |
| Yousuf et al., 2017 | Randomized, double-blind study | Probiotic powder | PI and GI | Significant reductions were observed in both PI and GI scores [31]. |

| | | | | |
|---|---|---|---|---|
| Janiani & Ravindran, 2022 | RCT; children | Yakult and enKor-D | *S. mutans* and PI | Both interventions reduced *S. mutans* levels; however, only Yakult significantly reduced PI [32]. |
| Zhou et al., 2025 | Double-blind RCT | Probiotic mouthwash | BOP, PI, GI, and cytokines | Probiotic use was associated with reductions in clinical and inflammatory parameters [33]. |
| Badri et al., 2021 | Controlled study; children | Probiotic and chlorhexidine | PI, pH, and *S. mutans* | PI and *S. mutans* levels were reduced following the interventions [34]. |
| Nisha et al., 2023 | RCT; orthodontic patients | Aloe vera, probiotic, and fluoride | *S. mutans* | No statistically significant differences were observed among the intervention groups [35]. |
| Kandaswamy et al., 2018 | RCT; children | Probiotic, chlorhexidine, and sesame oil | PI and GI | All three interventions produced significant reductions in PI and GI [36]. |
| Babina et al., 2024 | RCT | *S. salivarius* M18 | BOP and plaque | Reductions in plaque accumulation and bleeding on probing were observed [37]. |

Findings from clinical and interventional studies suggest that probiotic products may improve selected oral health outcomes, including dental plaque accumulation, gingival inflammation, and the composition of the oral microbiome. However, the magnitude and consistency of these effects varied across studies, likely reflecting differences in probiotic strains, formulations, intervention protocols, and study populations (Table 4).

**Table 4. Clinical and Interventional Studies Evaluating Probiotics in Dental Plaque and Oral Health**

| Reference | Study design | Intervention | Primary outcome | Key findings |
|---|---|---|---|---|
| Hu et al., 2019 | Interventional study | *L. casei* Shirota | Plaque microbiota | Changes in the relative abundance of selected bacterial genera were observed following the intervention [38]. |
| Li et al., 2024 | Clinical study | Toothpaste containing *L. paracasei* Probio-01 | BOP, GI, and PI | Reductions in clinical indices were observed following the intervention [39]. |
| Lewiyonah et al., 2025 | Experimental clinical study | *L. reuteri* | PI and salivary pH | PI decreased, whereas salivary pH increased following the intervention [40]. |
| Shenoy et al., 2017 | Randomized clinical study | *B. coagulans* | GI, BOP, and PI | Reductions in GI and BOP were observed following probiotic administration [41]. |
| Samsuri et al. | Clinical study | Probiotic intervention for 2 weeks | PI | PI was lower in the probiotic group than in the control group [42]. |
| Ingle et al., 2013 | Clinical trial | Probiotic mouthwash and chlorhexidine | PI, GI, and *mutans streptococci* (MS) | Both interventions demonstrated beneficial effects on the evaluated clinical and microbiological outcomes [43]. |

Comparative studies have indicated that the efficacy of probiotics in controlling dental plaque may vary relative to established agents such as chlorhexidine and fluoride. In some studies, probiotics demonstrated effects comparable to those of conventional interventions, whereas in others, they showed limited or differential efficacy. The probiotic strain and mode of administration appeared to be important determinants of treatment outcomes, underscoring the strain- and formulation-specific nature of probiotic interventions (Table 5).

**Table 5. Comparative and Other Interventional Studies Evaluating Probiotics for Dental Plaque Control**

| Reference | Study design / Model | Intervention | Primary outcome | Key findings |
|---|---|---|---|---|
| Patil et al., 2019 | In vivo | Probiotic milk and fluoride | *S. mutans* and PI | Comparable effects were reported for the two interventions [44]. |
| Manoharan et al., 2020 | RCT; schoolchildren | Homemade probiotic yogurt | Plaque-associated microorganisms | Bacterial levels decreased; however, the reduction in plaque accumulation was not statistically significant [45]. |
| Mishra et al., 2014 | RCT; children | Herbal, probiotic, and chlorhexidine interventions | *S. viridans* and PI | The probiotic intervention demonstrated the least pronounced effects among the treatment groups [46]. |
| Sharma et al., 2019 | Comparative study; children | Probiotic and chlorhexidine | PI and gingival inflammation | The probiotic intervention demonstrated greater improvements in the evaluated outcomes than chlorhexidine [47]. |
| Baxi et al., 2023 | Comparative study; orthodontic patients | Probiotic tablet, powder, and beverage | *S. mutans* | The greatest reduction in *S. mutans* levels was observed with the tablet formulation [48]. |
| Bianco et al., 2021 | Retrospective study | Ruterin Os® and Carioblis® | PI and GI | Both probiotic supplements were associated with improvements in the evaluated indices [49]. |
| Nilchian et al., 2024 | RCT | *S. salivarius* M18 and K12 | PI | An increase in PI was observed following the intervention [50]. |
| Caglar, 2014 | Clinical study; children | Yogurt containing *B. bifidum* | *Mutans streptococci* | No statistically significant difference was observed between the intervention and control groups [51]. |

Secondary evidence suggests that probiotics may serve as adjunctive agents in dental plaque management by modulating the oral microbiome, inhibiting cariogenic microorganisms, and interfering with biofilm formation. However, the available evidence remains heterogeneous, with substantial variation in probiotic strains, formulations, intervention protocols, and outcome measures. Further rigorously designed and standardized clinical studies are therefore needed to clarify the clinical efficacy of probiotics and determine the most appropriate strains, formulations, dosages, and treatment protocols (Table 6).

**Table 6. Review Studies and Secondary Evidence on the Role of Probiotics in Dental Caries and Plaque Control**

| Reference | Study design | Topic | Primary outcome | Conclusion |
|---|---|---|---|---|
| Sivamaruthi et al., 2020 | Review | Probiotics and dental caries | Anticariogenic mechanisms | Probiotics may influence dental caries through multiple potential mechanisms, including modulation of the oral microbiome and inhibition of cariogenic microorganisms [52]. |
| Shi et al., 2023 | Systematic review and meta-analysis; 43 RCTs | Probiotics and dental caries in children | Dental caries, *S. mutans*, and *Lactobacillus* spp. | Probiotic interventions were associated with reductions in dental caries and *S. mutans* levels, although considerable heterogeneity was reported across the included trials [53]. |
| Marttinen et al., 2012 | Short-term clinical study | *L. rhamnosus* GG and *L. reuteri* | Plaque acidogenicity and *mutans streptococci* (MS) | No statistically significant changes were observed in plaque acidogenicity or *mutans streptococci* levels following probiotic administration [54]. |

Taken together, the studies summarized in Tables 1–6 indicate that probiotics have promising potential for the prevention and control of dental plaque through several complementary mechanisms, including modulation of the oral microbiome, inhibition of pathogenic bacterial growth, reduction of microbial adhesion, and interference with biofilm formation. In vitro studies have provided mechanistic evidence supporting these effects, including the production of antimicrobial compounds and inhibition of cariogenic bacterial activity, whereas animal models have provided additional evidence of reduced biofilm formation and modulation of the plaque-associated microbial ecosystem.

Clinical trials further suggest that selected probiotic strains may reduce plaque accumulation, gingival inflammation, and the levels of specific oral pathogens. However, these effects have not been consistently demonstrated across all studies. Substantial heterogeneity in probiotic strains, dosages, intervention durations, delivery systems, study populations, and outcome measures may explain, at least in part, the variability in reported findings.

Overall, the available evidence supports the potential use of probiotics primarily as a complementary biological strategy alongside established plaque-control measures, including mechanical oral hygiene and appropriate chemical adjuncts, rather than as a replacement for conventional preventive and therapeutic approaches. Future research should focus on elucidating strain-specific effects, standardizing probiotic formulations and treatment protocols, and establishing their long-term clinical efficacy and safety for dental plaque management.

## Discussion

The findings of laboratory studies suggest that probiotics, particularly strains of *Lactobacillus* and *Bifidobacterium*, may inhibit the growth of bacteria associated with dental caries and periodontal disease through several complementary mechanisms, including the production of antimicrobial compounds, competition for adhesion sites on dental surfaces, reduction of bacterial attachment, and interference with biofilm formation. Nevertheless, the marked differences observed among probiotic strains indicate that their antimicrobial activity is largely strain specific and cannot be generalized across probiotic species or formulations [16–19].

Evidence from animal models further supports the potential of probiotics to reduce the microbial burden of dental plaque, inhibit extracellular matrix production, decrease *Streptococcus mutans* levels, and modify the microbial composition of plaque. These findings suggest that, beyond direct antibacterial activity, probiotics may influence the ecological characteristics of the oral environment, thereby creating conditions that are less favourable for the proliferation of cariogenic microorganisms [20–23].

Evidence from randomized controlled trials indicates that probiotic administration may improve several clinical and microbiological parameters of oral health, including plaque index (PI), gingival index (GI), bleeding on probing (BOP), and the abundance of cariogenic or periodontal pathogens such as *S. mutans*. However, the magnitude and consistency of these effects varied considerably among studies. Differences in probiotic strains, dosage, intervention duration, delivery systems, and study populations are likely to contribute to the observed heterogeneity [24–37].

Non-randomized clinical studies have likewise reported potentially beneficial effects of probiotics on gingival health, plaque-associated microbial communities, salivary pH, and clinical oral-health indices. Although these findings provide further support for the adjunctive use of probiotics, their interpretation should take into account the methodological limitations inherent in non-randomized designs and the variability in individual responses. Accordingly, probiotics may be considered a complementary strategy alongside established plaque-control measures rather than a substitute for conventional oral-hygiene practices [38–43].

Comparative studies have yielded mixed findings regarding the efficacy of probiotics relative to established antimicrobial agents such as chlorhexidine and fluoride. In some clinical settings, probiotic interventions produced effects comparable to, or potentially greater than, those observed with conventional agents. However, other studies failed to demonstrate a significant advantage of probiotics. These inconsistencies reinforce the importance of strain selection, formulation, dosage, and route of administration in determining clinical effectiveness [44–51].

Secondary evidence, including systematic reviews and other review-based studies, provides additional support for the potential role of probiotics in dental plaque and caries management. Their proposed benefits include modulation of the oral microbiota, reduction of *S. mutans*, inhibition of biofilm development, and interference with cariogenic processes. Nevertheless, considerable heterogeneity across the primary studies, together with the limited availability of long-term clinical data, prevents definitive conclusions regarding their sustained clinical effectiveness. Larger, well-designed, and methodologically standardized clinical trials are therefore warranted [52–54].

The potential effects of probiotics on dental plaque are mediated through multiple biological pathways. These include competition with pathogenic microorganisms for adhesion sites on dental surfaces; production of antimicrobial substances, such as bacteriocins, organic acids, and hydrogen peroxide; and inhibition of biofilm development. Probiotics may also contribute to ecological homeostasis within the oral cavity by modifying the composition of the oral microbiota, reducing the adhesion and persistence of *S. mutans* and other cariogenic bacteria, and potentially influencing host inflammatory responses. Through these interconnected mechanisms, probiotics may represent a promising biological adjunct for limiting plaque accumulation, reducing caries-associated microbial activity, and supporting gingival health (55).

## Conclusion

Probiotics represent a promising complementary biological strategy for the prevention and control of dental plaque through modulation of the oral microbiome, inhibition of pathogenic microorganisms, and interference with biofilm formation. Evidence from in vitro and animal studies suggests that selected strains of *Lactobacillus* and *Bifidobacterium* may reduce bacterial adhesion, suppress *Streptococcus mutans*, and modulate the microbial ecology of dental plaque. Clinical studies have also reported improvements in plaque accumulation, gingival inflammation, and selected microbiological parameters following probiotic administration.

However, the clinical evidence remains heterogeneous, largely owing to differences in probiotic strains, dosages, intervention durations, delivery systems, and study populations. Therefore, probiotics should currently be considered primarily as a complementary approach alongside established plaque-control strategies, including mechanical oral hygiene and appropriate chemical adjuncts, rather than as a replacement for conventional preventive measures.

Future research should focus on identifying effective strain-specific interventions, establishing standardized dosing and treatment protocols, and conducting adequately powered, long-term clinical trials to determine the durability, clinical relevance, and safety of probiotic-based interventions. Overall, probiotics may have an important future role in dental plaque management and oral-health promotion through targeted modulation of the oral microbiome.

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### Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

### Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki.

### Consent to participate

Informed consent was obtained from all individual participants included in the study.

### Author contributions

GHS and AGH: Conceptualization, the original draft writing, investigation, writing including reviewing and editing and investigation and formal analysis; AGH: Conceptualization, supervision, and project administration; GHS Conceptualization, the original draft writing, investigation, writing including reviewing and editing

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