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Natural Products That Potentially Affect Dental Enamel Remineralization and Act as Antibacterial Agents: A Narrative Literature Review

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ABSTRACT

Despite advances in the understanding of dental caries, both researchers and clinicians continue to face challenges in its prevention and management. While antibiotics can be effective in preventing caries, their overuse poses risks, such as adverse side effects and the development of antibiotic resistance. Fluoride has long been recognized for its anti-cariogenic properties, yet there remains a need for complementary alternatives. Natural products with antimicrobial and remineralizing properties offer promising potential, potentially reducing the health risks associated with chemical agents. This review aims to summarize the efficacy of natural substances with antibacterial and enamel-remineralizing properties that may serve as substitutes for synthetic agents. The findings may support future research and development in integrating natural products into routine dental practice. This narrative review was conducted between October 2024 and March 2025 using databases, such as Scopus, PubMed, and Google Scholar. The following keywords were used for the literature search: "natural antibacterial agent," "natural remineralizing agent," "dental caries prevention," "anticarious natural product," "oral health," and "dental caries." Searches were restricted to topics related to oral health. It was concluded that natural products demonstrate effective antibacterial and remineralizing properties and may serve as viable alternatives to synthetic dental agents in caries prevention.

Keywords: Dental caries, Natural remineralizing agents, Natural antibacterial agents.

1. Introduction

The year 2020 marked an unprecedented turning point globally with the onset and rapid spread of the SARS-CoV-2 virus, responsible for coronavirus disease 2019 (COVID-19). This event underscored the ever-present threat of emerging infectious diseases and highlighted the urgent need for preparedness against future viral outbreaks. Both communicable and non-communicable diseases continue to pose major challenges for researchers seeking effective treatments. A key difficulty lies in developing medications that offer therapeutic efficacy with minimal or no adverse effects. Despite significant advancements in medical technology and a deeper understanding of disease mechanisms, many conditions remain difficult to treat, with some lacking effective therapies altogether. This underscores the necessity for innovative approaches in drug discovery and development. Nature offers a vast reservoir of bioactive compounds, many of which remain unexplored and hold potential for future therapeutic applications (1).

Phytotherapy encompasses the therapeutic application of herbal substances or plant-derived extracts aimed at preventing and managing various health conditions. These natural remedies often involve the use of unpurified extracts or plant-based

formulations. Extensive research has been conducted to isolate and characterize the active compounds responsible for their therapeutic effects. Despite significant advances in modern medicine, plant-based treatments continue to be employed in the management of various pathological conditions and are often considered viable alternatives to conventional pharmaceuticals. Due to their diverse chemical compositions, natural products offer a valuable source of novel bioactive molecules with potential for drug development (2).

Natural products have some distinct benefits when searching for and developing new drugs. They are chemical novelties that can lead drug candidates for complicated targets compared to other sources. Moreover, naturally derived constituents exhibit a chemical diversity that is unmatched by any collection of synthetic chemicals. They can have bi- and tri-dimensional complex compositions to be efficiently absorbed and metabolized in the body (3). Moreover, research has shown that plant products have fewer adverse effects than commercial chemical agents (4). The worrying rise in antibiotic resistance and unfavorable side effects of antiseptics/antimicrobial compounds highlights the necessity for new ways to treat and prevent oral diseases. Consequently, research efforts have increasingly focused on identifying, developing, and optimizing naturally derived antimicrobial compounds capable of inhibiting bacterial proliferation and adhesion within dental and oral biofilms (5). However, several natural products are failing clinical trials because of their toxicity and problems with biocompatibility (6).

In the United States, dental caries represents the most widespread chronic disease among children. Early childhood caries is associated with pain and tooth loss, stunted growth, reduced weight gain, and adverse effects on quality of life. For young children, direct restoration placement or extractions of carious teeth can be traumatic experiences and, in some cases, may result in significant complications. According to estimates by the US Surgeon General in 2000, over 50 million school hours are missed annually due to dental-related concerns (7).

Stepwise excavation is one of the significant techniques utilized for selective removal of caries. This technique intentionally retains a layer of carious soft dentin above the pulp. The tooth is then sealed *via* a protective liner for a specific duration (30-45 days). By inducing the development of tertiary dentin before complete excavation, this approach aims to reduce the probability of pulp exposure. There is an ongoing debate on the residual bacteria in deep carious lesions. Some researchers have emphasized the seal as the main factor for this technique's success. Others have suggested using antibacterial agents to control the remaining viable bacteria (8).

Fluoride has been shown to prevent and reverse the carious process by enhancing remineralization, inhibiting demineralization, and considering its antibacterial properties. Fluoride has been regarded as the gold standard for preventing dental carious cavities since the 1950s. The use of highly concentrated fluoride products raised some safety concerns in the age of holistic dentistry, following the classification of fluoride as a chemical neurotoxicant. More appropriate are the growing worries that children nowadays are at risk of dental fluorosis due to their exposure to several sources of fluoride (9).

Public health officials have restricted fluoride in over-the-counter toothpaste between 1,000 and 1,500 ppm because of the limited "dose gap" between the advantages of caries depletion and the adverse toxic effects of fluoride. This dosage is lower and below the sufficient remineralization level of early carious lesions for children younger than 6 years (10).

New remineralizing agents are required to maximize the remineralization efficacy of fluoride on carious lesions and supplement its effect. Because natural products have fewer side effects and are effective in dentistry, there is a tendency to shift toward allaying the safety concerns. Several medicinal plant extracts have demonstrated the ability to inhibit the growth of dental biofilms by decreasing pathogen adhesion to the tooth surface, a crucial step in the formation of caries (11). It was reported that there is a gradual decrease in specific bacterial pathogens from the oral cavity by introducing a natural antimicrobial agent, thus contributing to a healthy relationship between the oral microbiome and the host (12).

Furthermore, these natural products can be integrated into chewing gum and lollipops. Chewing gum improves the remineralization of enamel by raising calcium and phosphate levels in the oral cavity through the increased volume of stimulated saliva during mastication, with concurrent ability to clear fermentable

carbohydrates and acids on the tooth surfaces (13). Also, it could alter the relationship between the oral microbiome and the host, which improves homeostasis and thus improves the oral microbiome's health (12). The approach of a lollipop in the form of a candy that is sugar-free and has remineralizing and antibacterial efficacy is a unique delivery system while also being kid-friendly. This raises the hope of finding a simple and effective way to deliver targeted intervention to young children at risk for dental caries (14).

To the best of our knowledge, no published review has comprehensively summarized the effective natural antibacterial and remineralizing products used in oral health. Therefore, the aim of this review is to enhance our understanding of how natural biomaterials can be applied in biomedical contexts. Specifically, it provides a comprehensive overview of current evidence regarding the use of natural products as remineralizing and antimicrobial agents in the promotion of oral health.

2. Materials and Methods

This narrative review explores and evaluates the efficacy of natural products as remineralizing and antibacterial agents in oral healthcare. Relevant studies were identified and synthesized to provide a qualitative assessment of current knowledge in this area.

2.1 Search Methods

The literature review was conducted by searching databases, such as Scopus, PubMed, and Google Scholar. The key phrases were utilized for database searching, including the search terms “natural antibacterial agent,” “natural remineralizing agent,” “dental caries prevention,” “anticarious natural product,” “oral health,” “dental caries.” The keywords were limited to dentistry and oral health. All results were reviewed and discussed within the team. We also conducted a narrative synthesis to summarize and describe the current findings.

2.2 Inclusion Criteria

We included articles that showed natural products with effective antibacterial and remineralizing effects on oral health. *In-vitro*, *In-vivo*, review articles were included. Language was limited to English. Additionally, only accessible articles were included.

2.3 Exclusion Criteria

During the literature selection process, specific exclusion criteria were applied. Commentary articles, letters to the editor, conference presentations, and studies without comprehensive coverage of oral health status or complete system analysis were omitted. Additionally, research lacking available full texts was excluded. Studies were not considered if they investigated natural products displaying either only remineralizing effects or only antibacterial effects—unless both effects were assessed together.

3. Results and Discussion

Several natural products exhibit both antibacterial and remineralizing effects on dental hard tissues. Many publications evaluated the antibacterial and remineralizing effects of many natural products; they are listed in Table 1. These natural products are:

3.1 Cranberry

Cranberry (*Vaccinium macrocarpum)* fruits contain abundant organic acids and biologically active phenolic compounds (5). Several *in vivo* and *in vitro* investigations have demonstrated that different cranberry compounds, fractions, and extracts exhibit marked antibacterial actions (15-18).

The bioactive polyphenolic components of cranberries possess virulence attenuating ability against many cariogenic virulence properties implicated in dental caries pathogenesis. Cranberry A-type proanthocyanidins and flavonols act on specific cariogenic virulence targets, including glucan synthesis, bacterial surface hydrophobicity, acid production, bacterial acidogenicity, and aciduricity. Without being bactericidal, cranberry phenols can disrupt these cariogenic virulence properties, which is a key quality essential for maintaining the advantages of the symbiotic resident oral microbiome and preventing the development of microbial resistance (19).

Polyphenols found in cranberry extracts are primarily proanthocyanidins. As dentin modifiers, proanthocyanidins interact with the exposed collagen matrix to cause collagen cross-linking, stabilizing the collagen. Additionally, they inhibit matrix metalloproteinases and cysteine cathepsins in dentin, improving the stability of the exposed collagen matrix against degradation by proteolytic enzymes. This stabilized collagen matrix could serve as a mechanical

barrier to inhibit further loss of minerals and the adverse effects of acid (20).

Table 1: Different studies that discussed the effectiveness of some natural products as oral antibacterial and remineralizing agents

Authors	Title / Study Design	Natural materials	Conclusions
Philip et al. (19)	Cranberry polyphenols: Natural weapons against dental caries. (Review of literature).	Cranberry	Cranberry polyphenols have several potential uses, such as adjunctive anticaries agents.
Sánchez et al. (5)	New evidence of antibacterial effects of cranberry against periodontal pathogens. (In-vitro study).	Cranberry extract	Cranberry showed a moderate antibacterial effect against periodontal pathogens in biofilms, but it had a relevant anti-biofilm property by affecting bacterial adherence in the first 6 h of biofilm development.
El Sayed et al. (20)	Evaluation of the remineralizing potential of cranberry and chitosan on demineralized dentin. (In-vitro study)	Cranberry extract and Phosphorylated chitosan	Phosphorylated chitosan and cranberry extract could be natural treatments to strengthen demineralized dentin.
Lakshmi et al. (65)	Effect of theobromine on antimicrobial activity (In-vitro study).	Cocoa	Theobromine possesses antibacterial properties. Compared to other commercially available fluoridated children's toothpastes, theobromine showed larger inhibition zones while not being fluoridated.
Irmaleny et al. (66)	The remineralization potential of cocoa (Theobroma cacao) bean extract increases the enamel microhardness. (In-vitro study).	Cocoa	Cocoa extract can be a substitute for fluorine remineralization and enhance the microhardness of enamel.
Hamasaeed et al. (23)	Assessing the impact of varied dark chocolate concentrations on enamel and dentine microhardness. (In-vitro study)	Cocoa	Immersing the specimens in different concentrations of dark chocolate significantly improved the microhardness of both enamel and dentine.
Elgamilyy et al. (28)	Laboratory evaluation of anti-plaque and remineralization efficacy of sugarless probiotic jelly candy supplemented with natural nano prebiotic additive. (In-vitro study)	Natural prebiotic grape seed extract	The nanoemulsion of grape seed extract and Lacticaseibacillus rhamnosus probiotic strain impregnated in jelly candy demonstrated both anti-cariogenic and remineralizing effects.
Nandakumar M. (67)	Comparative evaluation of grape seed and cranberry extracts in preventing enamel erosion: An optical emission spectrometric analysis. (In-vitro study)	Grape seed extract (GSE) and cranberry extract (CE)	The protective effect of GSE and CE was lower than that of the gold standard control group of stannous fluoride against enamel erosion. GSE demonstrated a higher remineralizing effect; however, there was no statistically significant difference between the two groups.
Göçmen et al. (33)	Effectiveness of some herbals on initial enamel caries lesion. (In-vitro study)	Ginger, rosemary and honey	Herbals (ginger, honey and rosemary) have enhanced remineralization of initial enamel caries.
Abdo et al. (68)	The remineralizing potential of some natural materials alone or combined with Zamzam water on demineralized enamel. (In-vitro study)	Honey, whey extract, and Zamzam water	Natural materials have a remineralizing effect on the enamel of teeth.
Bilgin et al. (32)	Remineralization potential of herbal mixtures. (In situ Study)	Ginger, honey, chocolate, and rosemary	All treatment systems showed enhanced remineralization, ginger-honey-chocolate and ReminPro being the most effective.

Ahmed et al. (69)	Antimicrobial effects of gum Arabic-silver nanoparticles against oral pathogens. (In-vitro study)	Gum Arabic	This study supports the prospective implementation of plant extract-mediated AgNPs in dental healthcare.
Abinaya et al. (70)	Antimicrobial efficacy of licorice extracts on most common endodontics pathogens. (In-vitro study)	Liquorice extract	Compared to aqueous extract, licorice ethanolic extract has a strong bactericidal effect. Therefore, it can be used as intracanal medicament in endodontic therapy routines.
Krishnakuma et al. (14)	Anticaries efficacy of liquorice lollipop. (Ex vivo study)	Liquorice extract	Liquorice lollipops effectively decreased S. mutans, but did not show a remineralizing potential.
Pooja et al. (40)	Effect of licorice candies on remineralization of initial enamel carious lesion. (In vitro and in vivo study)	Liquorice extract	Licorice extract has remineralizing potential and other medicinal properties.
Satyanegara et al. (71)	An in vitro study of the caries-arresting effect of propolis fluoride and silver diamine fluoride on dentine carious lesions.	Propolis	Propolis fluoride can be an alternative to silver diamine fluoride for arresting dentinal caries.
Prabhakar et al. (44)	Cavity disinfection in minimally invasive dentistry: A comparative evaluation of aloe vera and propolis: A randomized clinical trial. (In-vivo study)	Aloe vera and propolis	Bacteria cannot be entirely removed by hand excavation alone. Cavities treated with Aloe vera and propolis extracts showed a significant decrease in bacterial counts compared to the control group.
Ghorab and Ibraheim (72)	Effect of hesperidin on an etch-and-rinse adhesive system's antibacterial activity and adhesive properties. (In-vitro study)	Hesperidin	Hesperidin-modified dental adhesives could achieve a positive antibacterial effect without negatively affecting the adhesive characteristics.
Anani et al. (45)	Evaluation of the remineralization and antibacterial effects of natural versus synthetic materials on deep carious dentin. (A randomized controlled trial)	Propolis and hesperidin	Inhibiting the progression of caries and remineralizing carious tooth tissue were two promising effects of propolis and hesperidin medicines.
Balhaddad et al. (73)	Antibacterial activities of methanol and aqueous extracts of Salvadora persica against Streptococcus mutans biofilms. (In-vitro study)	Salvadora persica (miswak)	The methanol extract from S. persica may be used as a mouthwash or as an adjunctive oral hygiene tool.
Balto et al. (74)	Effectiveness of Salvadora persica extracts against common oral pathogens. (In-vitro study)	Salvadora persica	Ethanol and hexane extracts of S. persica showed to have maximum antimicrobial activity against S. mutans, S. salivarius, and S. sanguis at high concentrations.
Almas, Al-Zeid (75)	The immediate antimicrobial effect of a toothbrush and Miswak on cariogenic bacteria: A clinical study. (In-vivo study.)	Salvadora persica	Miswak has an immediate antimicrobial effect. Streptococcus mutans were more liable to miswak antimicrobial activity than Lactobacilli.
Machado et al. (76)	Triclosan-loaded chitosan as antibacterial agent for adhesive resin.	Chitosan	Triclosan-loaded chitosan incorporated at 5 wt.% into an experimental adhesive resin demonstrated the highest antibacterial efficacy both immediately and after six months, while also promoting stability at the dentin/adhesive interface over time.
Voina et al. (77)	Antimicrobial activity and the effect of green tea experimental gels on teeth surfaces.	Green tea	The experimental green tea extract demonstrated effectiveness against certain microorganisms commonly found in the oral cavity. Following bleaching with the experimental gel, surface

			parameters comparable to those of healthy enamel were achieved, indicating optimal surface quality.
Moslehitabar et al. (78)	Efficacy of an experimental CPP-ACP and fluoride toothpaste in prevention of enamel demineralization: In vitro study on bovine enamel	CPP-ACP	Each of the three remineralizing agents prevented enamel demineralization, but CPP-ACP proved to be more effective at depths of 50 and 120 μm.

3.2 Cocoa

Chocolate is one of those junk food products, and a common misconception holds that it is the main reason for tooth cavities, which is misleading. Dark chocolate is regarded as a natural food that is healthy and beneficial. Tooth decay may have resulted from the chocolate products' high sugar levels. Moreover, cocoa butter may form a protective film on tooth surfaces, which can resist harm from sugar (21).

The key to cocoa's dental benefits is theobromine, a naturally occurring alkaloid constituting 1%-4% of cocoa beans. It is an alkaloid of the cocoa plant with a chemical formula of 3.7-dimethylxanthine. Previously, it was known as xantheose, a bitter, crystalline powder insoluble in water. Theobromine reduces the incidence of tooth decay by strengthening tooth enamel In addition, it contains unsaturated free fatty acids, like oleic and linoleic acids, which are antibacterial for S. mutans (22).

Pre-roasted beans have been extracted from the cocoa bean husk during the processing of Theobroma cocoa. Two distinct types of cariostatic compounds have been found in cocoa bean husks, with one exhibiting antibacterial properties while the other demonstrates antiglucosyltransferase (GTF) activity. In cocoa bean husk extract, the larger molecular weight of polyphenolic molecules shows significant anti-glycosyltransferase activity. S. mutans secrete the glucosyltransferase enzymes responsible for converting sucrose into glucans, resulting in an adhesive and water-insoluble substance that firmly adheres to the tooth surface. The adhesive glucan, where acid accumulation occurs, plays a role in the formation of dental plaque, leading to localized demineralization of the tooth enamel surface (23).

The anti-carcinogenic effect of theobromine could be because the theobromine-forming medium enhances the remineralization potential of the tooth. A 1-ounce dark chocolate bar's theobromine content has a greater impact on tooth hardness than a 1.1% prescription sodium fluoride treatment. However, fluoride toothpaste has many benefits, such as increasing enamel resistance and strength; the drawback is that it is highly toxic if absorbed or ingested. The advantage of this theobromine is that it is nontoxic because of its non-fluoride content (24).

In an animal study, Sadeghpour (2007) found that theobromine was more effective than fluoride in preventing dental carious cavities. While fluoride is an effective enamel strengthener, high doses can cause side effects, such as dental fluorosis, tooth discoloration, and gastrointestinal irritation. On the other hand, theobromine was readily absorbed by the gut, metabolized, and cleared cleanly by humans (25).

Applying theobromine to the surface of the enamel will cause the hydroxyapatite crystals to increase in size, improving the enamel's resistance to acids and preventing demineralization. Theobromine contained in the cocoa extract will raise the hardness of tooth enamel *via* interstitial reaction with hydroxyl apatite crystals to replace the missing minerals. Since theobromine crystals are smaller than hydroxyapatite crystals, they will be easier to enter the tunnel and replace the ions in the apatite's composition. The ion replacement will change the physical properties of apatite (25).

3.3 Grape Seed Extract

Grape seed extract (GSE) from grapes produced in Turkey's Hağandede, Emir, and Kalecik Karasi wine cultivars demonstrated the most significant inhibitory efficacy against a range of bacteria, such as K. pneumoniae, E. coli, and S. aureus, at concentrations of 2.5%-5%. When tested against 21 gram-positive and gram-negative cocci strains, a grape seed extract product revealed that gram-positive cocci, especially S. aureus, were more vulnerable (26).

Studies have shown that proanthocyanin extract from grape seeds is regarded as a prebiotic agent, because it can specifically stimulate the probiotic microbiota while inhibiting the growth and activity of harmful bacteria (27,28).

Studies have also demonstrated that GSE facilitates

remineralization of early carious lesions through mechanisms distinct from those of fluoride. Its gallic acid content induces mineral deposition at lesion surfaces (29). Previous studies have shown that grape seeds have a large concentration of calcium content (55.74%) and a lower phosphorus concentration (15.34%). Accordingly, GSE may contribute to forming calcium phosphate crystals, enhancing the remineralization of enamel sub-surface lesions (30).

3.4 Honey, Ginger

Honey is used in many ancient cultures for both nutritional and therapeutic purposes. The belief that honey is a nutrient, a drug, and an ointment has been carried into present times. Due to its high sugar saturation and low water activity, honey naturally restricts microbial growth. Studies have demonstrated that manuka honey has strong antibacterial activity and is probably non-carcinogenic. Honey also has potent, broad-spectrum antibacterial activity. The average pH value of honey is 3.9, so it is acidic and can inhibit the growth of pathogens, since most prefer a pH of 4.0 to 4.5. However, this effect will be reduced if honey is diluted with saliva, which will increase the pH. Dilution also results in a 2500-50,000 times increase in enzyme activity, and the action of the enzyme glucose oxidase and the production of hydrogen peroxide, which is an oxidizing agent, will increase. In honey, hydrogen peroxide is very low, yet it is still an effective antibacterial agent compatible with cellular preservation (31,32).

Ginger rhizome (Zingiber officinale Roscoe, Zingiberaceae) is recognized among natural food substances, possessing antimicrobial activity and having a long-standing history of use as both a culinary spice and a medicinal plant. It is a naturally derived, non-toxic compound classified as “generally recognized as safe” (GRAS) by the U.S. Food and Drug Administration. Notably, its characteristic pungency arises from essential oil constituents rich in polyphenolic ketones, which exhibit diverse pharmacological properties (33).

It was reported that ginger and honey were more effective than gentamycin against S. mutans. Furthermore, they were demonstrated as potent remineralizing agents. The high remineralization was probably due to ginger's antimicrobial properties and high fluoride content. Additionally, the pH of the ginger and honey mixture was essentially neutral (pH 6.35). Honey, with its low pH, may activate the fluoride release from ginger at the time of application, resulting in higher remineralization (32).

3.5 Gum Arabic

Gum Arabic (GA) is a gummy exudate derived from the umbrella-shaped branches of Acacia seyal and Acacia senegal trees. Traditionally, it has been applied as an oral hygiene agent, with formulations containing GA shown to substantially reduce gingival and plaque index levels (34). Since it resists degradation in the stomach and undergoes fermentation into short-chain fatty acids in the large intestine, GA functions as a prebiotic that promotes the growth and activity of beneficial intestinal microorganisms, thereby contributing to several positive health outcomes (35). Furthermore, GA comprises cyanogenic glycosides and a variety of antimicrobial enzymes, including oxidases, peroxidases, and pectinases.

Gum Arabic predominantly consists of high-molecular-weight polysaccharides. Additionally, its elevated content of calcium, magnesium, and potassium salts plays a role in enhancing tooth remineralization. The calcium ions present in gum Arabic can substitute those lost from hydroxyapatite crystals, thereby aiding in the prevention of further enamel demineralization (36).

3.6 Licorice

Licorice is a well-known herb in traditional Chinese medicine. It was thought to relieve pain, tonify the stomach and spleen, reduce coughing, and clean phlegm. The main medicinal parts of licorice are the roots and rhizomes. Numerous studies have shown that licorice has various pharmacological activities, including antiviral, anti-inflammatory, antitumor, and antimicrobial properties (37–39). Especially in developing countries, viral and other microbial infections play an essential role in some highly prevalent diseases, further underscoring the importance of licorice’s broad spectrum of therapeutic effects (40).

Nearly 300 flavonoids and more than 20 triterpenoids can be found in licorice. The main active components that possess antiviral and antimicrobial activities include glycyrrhizin (GL), 18β-glycyrrhetinic acid (GA), liquiritigenin (LTG), licochalcone A (LCA), licochalcone E (LCE), and glabridin (GLD). Furthermore, research on flavonoids has found that they

have the potential for remineralization by raising the availability of calcium and phosphate ions (41). Additionally, the ethanolic extract of licorice was found to have a potent bactericidal effect against C. albicans and E. faecalis over aqueous extract. So, it can be used as an intracanal medicament in daily endodontic therapy (42).

3.7 Propolis

Propolis, a bee-derived substance, has drawn increasing scientific interest due to its safe profile and biological activities attributed to its polyphenolic compounds. It is a resinous material composed mainly of flavonoid derivatives collected from tree exudates, honeybee secretions, and various plant sources. This natural product demonstrates anti-inflammatory, antimicrobial, antitumor, antiviral, anesthetic, and regenerative properties. Its polyphenolic components are recognized as potent bioactive agents capable of modulating pathways involved in the pathophysiology of inflammatory disorders (43).

Propolis may promote dentin remineralization owing to its flavonoid content, which enhances reparative dentin formation through the upregulation of transforming growth factor β1 (TGF-β1). This growth factor interacts with the extracellular matrix to stimulate collagen synthesis. In addition, flavonoids exert antimicrobial effects by denaturing microbial proteins and nucleic acids. The inhibition of bacterial growth reduces demineralization and facilitates mineral deposition. Moreover, trace minerals such as copper, iron, and zinc, along with arginine, bioflavonoids, provitamin A, and B-complex vitamins, contribute to the nucleation and formation of new hydroxyapatite crystals (8).

3.8 Aloe Vera

Aloe Barbadensis Mill, commonly known as Aloe vera, is a short succulent herb that resembles a cactus with thick, spiky, green dagger-shaped leaves containing a clear, viscous gel. This gel exhibits potent antiviral, antibacterial, and antifungal effects. The antimicrobial properties of Aloe vera are primarily attributed to pharmacologically active compounds, such as aloe-emodin and aloin, the main anthraquinones in the plant. These compounds inhibit bacterial protein synthesis, explaining their antimicrobial activity. Aloe vera's bioactive constituents also include multiple other compounds acting synergistically to exert broad-spectrum antimicrobial effects (44).

The gel itself is made up of 98.5% water. The remaining elements are a mixture of minerals, vitamins, polysaccharides, enzymes, phenolic compounds, and organic acids in different ratios. Polyphenols, including anthraquinones, appear to be the vital active chemical compounds responsible for the capacity of A. vera gel to provoke remineralization (11).

3.9 Hesperidin

Hesperidin, a natural flavonoid predominantly found in orange fruit peel and pulp, consists of a glycogen sugar moiety linked to a non-sugar aglycone component. It exhibits anti-inflammatory, antioxidant, antimicrobial, and collagen cross-linking properties that support the remineralization process and help prevent caries formation (45).

3.10 Salvadora persica (Miswak)

Salvadora persica, also known as the Arak tree, is a member of the Salvadora family and is widely recognized as the toothbrush tree due to its historical use in oral hygiene. With a crooked trunk, it is an upright evergreen that grows as a small tree or shrub. It rarely exceeds one foot in diameter and can reach up to three meters in height. Commonly known as Miswak, it has been used as a natural toothbrush for centuries, especially by Muslims in the Middle East. The plant has been highlighted by researchers for its diverse biological activities in medicine, pharmacology, and dentistry (46). Miswak has been used as a natural toothbrush for centuries, especially by Muslims in the Middle East. The plant has been highlighted by researchers for its diverse biological activities in medicine, pharmacology, and dentistry. Miswak is reported to have remineralization potential due to its antibacterial effects and has been proposed as a natural alternative to fluoride toothpaste. Also, it was noted that Salvadora persica was classified as a broad-spectrum antimicrobial and was effective against various oral pathogens. It also possesses antibacterial qualities, especially against Streptococcus mutans (47).

Chewing the Miswak stick increases salivary flow, which is essential for maintaining oral homeostasis by balancing intraoral pH. Clinical studies, such as that by Khalil et al. (2013), revealed that Miswak users exhibit higher levels of salivary sodium, calcium, and phosphate

in the dental biofilm compared to toothbrush users. Saliva is well-known for its role in enamel remineralization, and Miswak stimulates the release of phosphate ions that help buffer the dental biofilm pH. This buffering action contributes to a decreased risk of caries, highlighting Miswak's potential role in caries prevention through its effects on saliva composition and pH regulation (48).

3.11 Chitosan

Chitosan is a biopolymer derived from about 70% deacetylation of chitin, a naturally occurring complex carbohydrate found in the exoskeletons of shrimps, crustaceans, and insects (49).

Due to its biodegradability, minimal toxicity, and biocompatibility, chitosan and its derivatives have gained prominence as promising biomaterials in dentistry. Chitosan has been used as both direct and indirect pulp capping agents, displaying considerable antimicrobial efficacy, especially against Enterococcus faecalis (50). Its capacity to promote remineralization has garnered significant interest, particularly for facilitating enamel and dentin regeneration (51).

Additionally, chitosan is incorporated in triple antibiotic intracanal medicaments and employed for smear layer removal during root canal treatment. It is also used in guided tissue and bone regeneration, as well as to support healing following periodontal surgeries. The modification of restorative materials, such as glass ionomer cements, composites, and dental adhesives with chitosan enhances their antimicrobial properties and bond strength to dental tissues. In oral surgical applications, chitosan is utilized to control bleeding, assist in oral reconstruction, serve as a bone graft substitute, and facilitate the repair of temporomandibular joint discs (50).

Phosphorylated chitosan, one of the various chitosan derivatives, exhibits enhanced bactericidal activity along with its inherent biocompatibility and bone-promoting properties. Zhang et al. demonstrated that applying phosphorylated chitosan to partially demineralized dentin supports biomimetic remineralization. The study showed notable calcium and phosphate ion deposition on the dentin surface, indicating effective induction of mineral phase formation and crystal nucleation. This highlights phosphorylated chitosan’s potential in promoting enamel and dentin repair by mimicking natural mineralization processes (52).

3.12 Green Tea

Green tea is characterized by its unique composition, which includes carbohydrates, such as fructose, sucrose, and glucose, along with cellulose and pectin. It also contains lipid components, like linoleic and linolenic acids and sterols, including stigmasterol. Minerals constitute approximately 5%-7% of green tea's content, mainly potassium, phosphorus, calcium, and magnesium, with trace amounts of zinc, manganese, and copper. Additionally, green tea contains vitamins, chlorophyll pigments, and carotenoids (53). It has been used to enhance oral health by addressing conditions, such as periodontal disease, tooth loss, dental caries, halitosis, and even preventing oral malignancies (54).

Tea contains approximately 4000 bioactive molecules, with polyphenols comprising nearly one-third of these components. Teas are particularly abundant in flavonoid polyphenols, primarily catechins and their derivatives, such as epicatechin (EC), epigallocatechin (EGC), epicatechin gallate (ECG), and epigallocatechin gallate (EGCG) (55). EGCG has therapeutic potential by disrupting bacterial adhesion, regulating inflammatory pathways, and diminishing oxidative stress. Evidence from clinical studies indicates that green tea can enhance periodontal health by decreasing pocket depth, inflammation, and bleeding. It has been demonstrated as an effective adjunct to standard periodontal treatments, such as scaling and root planning, and can be integrated into oral hygiene products, including mouthwashes and dentifrices (56).

3.13 Casein Phosphopeptide-Amorphous Calcium Phosphate (CPP–ACP)

A novel remineralization strategy involves the use of calcium phosphate particles stabilized by casein milk protein, which generates a supersaturated environment of amorphous calcium phosphate around the tooth surface under the acidic conditions of dental plaque, thereby promoting the remineralization process (57,58). Casein milk protein consists of a cluster of protein molecules, technically referred to as casein phosphopeptide–amorphous calcium phosphate (CPP-ACP) (59).

When combined with fluoride, CPP–ACP enhances remineralization by forming acid-resistant fluorapatite-like structures. Studies demonstrate its effectiveness in treating white spot lesions, early childhood caries, root caries, dental erosion, and dentin hypersensitivity. CPP–

ACP is included in tooth creams, gums, rinses, and restorative materials, with remineralization outcomes comparable to or exceeding those of traditional fluoride products. Its concurrent use with low-level fluoride is often advised for improved efficacy (60).

Glycomacropeptide (GMP), a hydrophilic fragment derived from casein, has garnered significant attention for its biological properties, including its potential to reduce dental caries by altering the microbial composition of dental plaque from Streptococci to less cariogenic Actinomyces species (59). Consequently, incorporating GMP into chewing gum or toothpaste formulations has been proposed as an effective strategy for caries prevention and plaque control. Moreover, the probiotic approach represents a novel preventive and therapeutic modality that competes with oral pathogens for adhesion sites and nutrients while restoring microbial ecological balance within the oral cavity (61,62). Previous studies have indicated that the long-term consumption of milk containing the probiotic strain Lactobacillus rhamnosus GG (ATCC 53103) exerts a beneficial effect on children's dental health without evidence of increased plaque acidity (63,64).

4. Conclusions

Natural products have shown promise as effective alternatives to synthetic agents, such as fluoride, which has been classified as a chemical neurotoxicant. These natural agents not only support good oral hygiene, but may also serve as safe, non-toxic substitutes for fluoridated toothpaste, particularly for children. Examples include:

- **Cranberry extract** has demonstrated potential in reinforcing demineralized dentin and exhibits moderate antibacterial activity against periodontal pathogens within biofilms.
- **Theobromine** possesses antimicrobial properties and has been shown to produce larger zones of bacterial inhibition compared to several commercially available fluoridated children's toothpastes. Additionally, cocoa extract has been found to enhance enamel microhardness, offering a viable alternative to fluoride in remineralization therapies.
- **Nanoemulsions of grape seed extract,** incorporated into jelly candies, exhibit both remineralizing and anti-cariogenic effects.
- **Ethanolic extract of licorice** has demonstrated strong bactericidal effects and may be used as an intracanal medicament in endodontic therapy. Furthermore, licorice lollipops have been effective in reducing Streptococcus mutan levels.
- **Propolis-fluoride formulations** could serve as alternatives to silver diamine fluoride for the arrest of dentinal caries.
- Since mechanical excavation does not completely eliminate bacteria, the use of **Aloe vera and propolis** extracts in treated cavities has been associated with significant reductions in bacterial counts.
- **Hesperidin-modified dental adhesives** have shown effective antibacterial activity without compromising adhesive properties. Both hesperidin and propolis have demonstrated promising effects in promoting remineralization and inhibiting the progression of carious lesions.
- **Methanolic extract of Salvadora persica** (Miswak) shows potential as a mouthwash or adjunctive oral hygiene agent.
- **Miswak,** particularly its ethanol and hexane extracts, has demonstrated significant antimicrobial effects, especially against S. mutans, S. sanguis, and S. salivarius at higher concentrations.
- **Chitosan**'s biocompatibility, biodegradability, and antibacterial properties make it a valuable natural agent in dentistry, particularly for tooth remineralization and tissue regeneration. Its molecular structure allows effective ion delivery and strong interaction with dental tissues, while its non-toxic and non-allergenic nature supports safe clinical use. These multi-functional attributes position chitosan as a promising material for advancing dental restorative and regenerative therapies,
- There is a clear link between **green tea** consumption and oral health. The polyphenolic compounds in green tea exhibit multiple biological activities—antioxidant, anti-inflammatory, antibacterial, and antiviral effects that contribute to preventing periodontal and other oral diseases. Incorporating green tea consumption into daily routines, such as during meals or breaks, represents a simple practice that can enhance overall oral health status.
- **CPP-ACP** is an adjunct to fluorides for noninvasive management of early caries, root dentinal caries, dental erosion, and dentine hypersensitivity. Its delivery forms include commercial toothpaste products that combine CPP-ACP with fluoride to enhance remineralization.

A key distinction between natural and synthetic agents lies in the time required to achieve therapeutic effects. Natural agents typically act more slowly, likely due to their lower concentrations of active ingredients compared to synthetic counterparts.

Future perspectives for research on natural products' antibacterial and remineralizing effects on tooth structure are warranted and may include the following:

- Additional clinical trials are warranted to evaluate and compare the efficacy of natural and synthetic materials in promoting oral health.
- Further in vitro and in vivo investigations are needed to assess the performance of natural products relative to the most effective antibacterial and remineralizing agents.
- Continued clinical research is essential to determine pulpal responses to these applied materials and to facilitate the development of commercially available natural products with both remineralizing and antibacterial properties. Such agents could serve as preventive or therapeutic alternatives and may also be incorporated into confectionery products, given their beneficial effects on oral health, cost-effectiveness, accessibility, and ease of application.

Conflict of Interests

The authors declare that there are no competing interests regarding this work.

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References

1. Dzobo K. The role of natural products as sources of therapeutic agents for innovative drug discovery. Compr Pharmacol. 2022;2:408-422.
2. Janakiram C, Venkitachalam R, Fontelo P, Iafolla TJ, Dye BA. Effectiveness of herbal oral care products in reducing dental plaque & gingivitis: A systematic review and meta-analysis. BMC Complement Med Ther. 2020;20:43.
3. Calixto JB. The role of natural products in modern drug discovery. An Acad Bras Ciênc. 2019;91:e20190105.
4. Ningsih DS, Idroes R, Bachtiar BM, Khairan. The potential of five therapeutic medicinal herbs for dental treatment: A review. IOP Conf Ser Mater Sci Eng. 2019;523:012009.
5. Sánchez MC, Ribeiro-Vidal H, Bartolomé B, Figuero E, Moreno-Arribas MV, et al. New evidences of antibacterial effects of cranberry against periodontal pathogens. Foods. 2020;9:246.
6. Elkordy AA, Haj-Ahmad RR, Awaad AS, Zaki RM. An overview on natural product drug formulations from conventional medicines to nanomedicines: Past, present and future. J Drug Deliv Sci Technol. 2021;63:102459.
7. US Preventive Services Task Force. Screening and interventions to prevent dental caries in children younger than 5 years: US preventive services task force recommendation statement. JAMA. 2021;326:2172-2178.
8. Anani H, Elasser D, Niazy M, Jamil W, Elsharkawy D. Evaluation of the remineralization and antibacterial effect of natural *versus* synthetic materials on deep carious dentin: A randomized controlled trial. Dent Med Probl. 2023;60:87-97.
9. Grandjean P, Landrigan PJ. Neurobehavioural effects of developmental toxicity. Lancet Neurol. 2014;13:330-338.
10. Philip N. State-of-the-art enamel remineralization systems: The next frontier in caries management. Caries Res. 2019;53:284-295.
11. Al Haddad T, Khoury E, Farhat Mchayleh N. Comparison of the remineralizing effect of brushing with Aloe vera versus fluoride toothpaste. Eur J Dent. 2021;15:133-138.
12. Zarco MF, Vess TJ, Ginsburg GS. The oral microbiome in health and disease and the potential impact on personalized dental medicine. Oral Dis. 2012;18:109-120.
13. Mickenautsch S, Leal SC, Yengopal V, Bezerra AC, Cruvinel V. Sugar-free chewing gum and dental caries: A systematic review. J Appl Oral Sci. 2007;15:83-88.
14. Krishnakumar G, Gaviappa D, Guruswamy S. Anticaries efficacy of liquorice lollipop: An ex vivo study. J Contemp Dent Pr. 2018;19:937-942.
15. Koo H, Nino de Guzman P, Schobel BD, Vacca Smith AV, Bowen WH. Influence of cranberry juice on glucan-mediated processes involved in Streptococcus

mutans biofilm development. Caries Res. 2006;40:20-27.
16. Cote J, Caillet S, Doyon G, Dussault D, Sylvain JF, et al. Antimicrobial effect of cranberry juice and extracts. Food Control. 2011;22:1413-1418.
17. Wojnicz D, Tichaczek-Goska D, Korzekwa K, Kicia M, Hendrich AB. Study of the impact of cranberry extract on the virulence factors and biofilm formation by Enterococcus faecalis strains isolated from urinary tract infections. Int J Food Sci Nutr. 2016;67:1005-1016.
18. Nogueira MC, Oyarzabal OA, Gombas DE. Inactivation of Escherichia coli O157:H7, Listeria monocytogenes, and Salmonella in cranberry, lemon, and lime juice concentrates. J Food Prot. 2003;66:1637-1641.
19. Philip N, Walsh LJ. Cranberry polyphenols: Natural weapons against dental caries. Dent J. 2019;7:20.
20. El Sayed M, Niazy M, Farouk H. Evaluation of remineralizing potential of cranberry and chitosan on demineralized dentin: (An in vitro study). Al-Azhar J Dent. 2022;9:83-93.
21. Srivastava A, Mahmood SE, Srivastava PM, Shrotriya VP, Kumar B. Nutritional status of school-age children: A scenario of urban slums in India. Arch Public Heal. 2012;70:8.
22. Ferrazzano GF, Amato I, Ingenito A, De Natale A, Pollio A. Anti-cariogenic effects of polyphenols from plant stimulant beverages (cocoa, coffee, tea). Fitoterapia. 2009; 80:255-262.
23. Hamasaeed NH, Toma IS, Abdullah AO, Kadir SK. Assessing the impact of varied dark chocolate concentrations on enamel and dentine microhardness. Appl Sci. 2024;14:382.
24. Amaechi BT, Porteous N, Ramalingam K, Mensinkai PK, Ccahuana Vasquez RA, et al. Remineralization of artificial enamel lesions by theobromine. Caries Res. 2013;47:399-405.
25. Arman S. A neural network analysis of theobromine *vs*. fluoride on theenamel surface of human teeth. Diss Abstr Int. 2007;68:150.
26. Shrestha B, Theerathavaj ML, Thaweboon S, Thaweboon B. In vitro antimicrobial effects of grape seed extract on peri-implantitis microflora in craniofacial implants. Asian Pac J Trop Biomed. 2012;2:822-825.
27. Pistol GC, Marin DE, Dragomir C, Taranu I. Synbiotic combination of prebiotic grape pomace extract and probiotic Lactobacillus sp. reduced important intestinal inflammatory markers and in-depth signalling mediators in lipopolysaccharide-treated Caco-2 cells. Br J Nutr. 2019;121:291-305.
28. Elgamily HM, El-Sayed SM, El-Sayed HS, Youssef AM. Laboratory evaluation of anti-plaque and remineralization efficacy of sugarless probiotic jelly candy supplemented with natural nano prebiotic additive. Sci Rep. 2023;13:10977.
29. Xie Q, Bedran-Russo AK, Wu CD. In vitro remineralization effects of grape seed extract on artificial root caries. J Dent. 2008;36:900-906.
30. Mironeasa S, Mironeasa C, Codină GG. Evaluation of mineral element content in grape seed and defatted grape seed. Food Environ Saf J. 2017;9:2559-6381.
31. Stephen-Haynes J. Evaluation of a honey-impregnated tulle dressing in primary care. Br J Community Nurs. 2004;Suppl:S21-S27.
32. Göçmen G, Yanikoğlu F, Tağtekin D. Remineralization potential of herbal mixtures: An in situ study. Paripex Indian J Res. 2016;5:264-268.
33. Bilgin Göçmen G, Yanikoglu F, Tagtekin D, Stookey GK, Schemehorn BR, et al. Effectiveness of some herbals on initial enamel caries lesion. Asian Pac J Trop Biomed. 2016;6:846-850.
34. Al-Jubori Y, Ahmed NTB, Albusaidi R, Madden J, Das S, et al. The efficacy of gum Arabic in managing diseases: A systematic review of evidence-based clinical trials. Biomolecules. 2023;13:138.
35. Ahmed AA. Health benefits of gum Arabic and medical use. Gum Arab Acad Press. 2018:183-210.
36. Hesham Samaha A, Hesham A, ElAziz R, Raafat HR. Remineralization efficacy of gum Arabic varnish vs. fluoride varnish and CPP-ACP with fluoride based varnish in initial carious lesions over 6 months follow up: A randomized controlled clinical trial. Adv Dent J. -2023;5:919-933.
37. Bodet C, La VD, Gafner S, Bergeron C, Grenier D. A licorice extract reduces lipopolysaccharide-induced proinflammatory cytokine secretion by macrophages and whole blood. J Periodontol. 2008;79:1752-1761.
38. Lee CK, Park KK, Lim SS, Park JHY, Chung WY. Effects of the licorice extract against tumor growth and cisplatin-induced toxicity in a mouse xenograft model of colon cancer. Biol Pharm Bull. 2007;30:2191-2195.
39. Jain E, Pandey RK, Khanna R. Liquorice root extracts as potent cariostatic agents in pediatric practice. J Indian Soc Pedod Prev Dent. 2013;31:146-152.

40. Pooja HR, Nagar P, Mascarenhas AN, Chandana KCH, Vatsala N, et al. Effect of liquorice candies on remineralization of initial enamel carious lesion. Int J Clin Pediatr Dent. 2023;16:S33-S38.
41. Wang L, Yang R, Yuan B, Liu Y, Liu C. The antiviral and antimicrobial activities of licorice, a widely-used Chinese herb. Acta Pharm Sin B. 2015;5:310-315.
42. Abinaya K, Divya R, Asha J, Subha A, Sneha SK, et al. Antimicrobial efficacy of liquorice extracts on most common endodontics pathogens. J Pharm Bioallied Sci. 2023;15:S760-S763.
43. Moccia S, Nucci L, Spagnuolo C, d'Apuzzo F, Piancino MG, et al. Polyphenols as potential agents in the management of temporomandibular disorders. Appl Sci. 2020;10:5305-5325.
44. Prabhakar AR, Karuna YM, Yavagal C, Deepak BM. Cavity disinfection in minimally invasive dentistry: Coparative evaluation of Aloe vera and propolis: A randomized clinical trial. Contemp Clin Dent. 2015;6:24-31.
45. Anani H, Elasser D, Niazy M, Jamil W, Elsharkawy D. Evaluation of the remineralization and antibacterial effects of natural *versus* synthetic materials on deep carious dentin: A randomized controlled trial. Dent Med Probl. 2023;60:87-97.
46. Aljarbou F, Almobarak A, Binrayes A, Alamri HM. Salvadora persica's biological properties and applications in different dental specialties: A narrative review. Evid Based Complement Altern Med. 2022;2022:8667687.
47. Irmaleny I, Fatriadi F, Christovher C. Natural materials' potential as alternative teeth remineralization agents: A scoping review. Eur J Dent. 2024;18:468-476.
48. Khalil WA, Sukkar MY, Gismalla BG. Oral health and its relation to salivary electrolytes and pH in miswak and brush users. Khar Med J. 2013;6:859-863.
49. Shoueir KR, El-Desouky N, Rashad MM, Ahmed MK, Janowska I, et al. Chitosan based nanoparticles and nanocapsules: overview, physicochemical features, applications of a nanofibrous scaffold, and bioprinting. Int J Biol Macromol. 2021;167:1176-1197.
50. Kmiec M, Pighinelli L, Tedesco MF, Silva MM, Reis V. Chitosan properties and applications in dentistry. Adv Tissue Eng Regen Med Open Access. 2017;2:00035.
51. Nimbeni SB, Nimbeni BS, Divakar DD. Role of chitosan in remineralization of enamel and dentin: A systematic review. Int J Clin Pediatr Dent. 2021;14:562-568.
52. Xu Z, Neoh KG, Lin CC, Kishen A. Biomimetic deposition of calcium phosphate minerals on the surface of partially demineralized dentine modified with phosphorylated chitosan. J Biomed Mater Res B Appl Biomater. 2011;98:150-159.
53. Narotzki B, Reznick AZ, Aizenbud D, Levy Y. Green tea: A promising natural product in oral health. Arch Oral Biol. 2012;57:429-435.
54. Suyama E, Tamura T, Ozawa T, Suzuki A, Iijima Y, et al. Remineralization and acid resistance of enamel lesions after chewing gum containing fluoride extracted from green tea. Aust Dent J. 2011;50:394-400.
55. Vyas T, Nagi R, Bhatia A, Bains SK. Therapeutic effects of green tea as an antioxidant on oral health: A review. J Family Med Prim Care. 2021;10:3998-4001.
56. Paczkowska-Walendowska M, Grzegorzewski J, Kwiatek J, Leśna M, Cielecka-Piontek J. Green tea: A novel perspective on the traditional plant's potential in managing periodontal diseases. Pharm. (Basel). 2025;18:409.
57. Reynolds EC. Anticariogenic complexes of amorphous calcium phosphate stabilized by casein phosphopeptides: A review. Spec Care Dent. 1998;18,:8-16.
58. Lata S, Varghese NO, Varughese JM. Remineralization potential of fluoride and amorphous calcium phosphate-casein phospho peptide on enamel lesions: An in vitro comparative evaluation. J Conserv Dent. 2010;13:42-46.
59. Kumar VL, Itthagarun A, King NM. The effect of casein phosphopeptide-amorphous calcium phosphate on remineralization of artificial caries-like lesions: An in vitro study. Aust Dent J. 2008;53:34-40.
60. Divyapriya GK, Yavagal Puja C, Veeresh DJ. Casein phosphopeptide-amorphous calcium phosphate in dentistry: An update. Int J Oral Health Sci. 2016;6:18-25.
61. Marsh PD, Head DA, Devine DA. Ecological approaches to oral biofilms: Control without killing. Caries Res. 2015;49:46-54.
62. Marsh PD. The commensal microbiota and the development of human disease: An introduction. J Oral Microbiol. 2015;7:29128.
63. Keller MK, Twetman S. Acid production in dental plaque after exposure to probiotic bacteria. BMC Oral Heal. 2012;12:44.
64. Näse L, Hatakka K, Savilahti E, Saxelin M, Pönkä A,

et al. Effect of long-term consumption of a probiotic bacterium, Lactobacillus rhamnosus GG, in milk on dental caries and caries risk in children. Caries Res. 2001;35:412-420.

65. Lakshmi A, Vishnurekha C, Baghkomeh PN. Effect of theobromine in antimicrobial activity: An in vitro study. Dent Res J (Isfahan). 2019;16:76-80.
66. Irmaleny I, Taofik H, Sulistianingsih S. The remineralization potential of cocoa (Theobroma cacao) bean extract to increase the enamel micro hardness. Padjadjaran J Dent. 2017;29.
67. Nandakumar M, Nasim I. Comparative evaluation of grape seed and cranberry extracts in preventing enamel erosion: An optical emission spectrometric analysis. J Conserv Dent. 2018;21:516-520.
68. Abdo R, Niazy M, Gad N. The remineralizing potential of some natural materials alone or combined with Zamzam water on demineralized enamel. Al-Azhar Dent J Girls. 2021;8:27-33.
69. Ahmed O, Sibuyi NRS, Fadaka AO, Madiehe AM, Maboza E, et al. Antimicrobial effects of gum Arabic-silver nanoparticles against oral pathogens. Bioinorg Chem Appl. 2022;13:9602325.
70. Abinaya K, Divya R, Asha J, Subha A, Sneha S, et al. Antimicrobial efficacy of liquorice extracts on the most common endodontic pathogens. J Pharm Bioallied Sci. 2023;15:760-763.
71. Satyanegara A, Darwita RR, Setiawati F, Adiatman M, Muhammad R. An in vitro study of caries arresting effect of propolis fluoride and silver diamine fluoride on dentine carious lesions. J Inter Dent Med Res. 2017;10:751-756.
72. Ghorab S, Ibraheim A. Effect of hesperidin on an etch-and-rinse adhesive system's antibacterial activity and adhesive properties. Egypt Dent J. 2018;64:3801-3812.
73. Balhaddad AA, Mokeem L, Melo MAS, Gregory RL. Antibacterial activities of methanol and aqueous extracts of Salvadora persica against Streptococcus mutan biofilms: An in vitro study. Dent J. (Basel). 2021;9:143.
74. Balto H, Al-Sanie I, Al-Beshri SAA. Effectiveness of Salvadora persica extracts against common oral pathogens. Saudi Dent J. 2017;29:1-6.
75. Almas K, Al-Zeid Z. The immediate antimicrobial effect of a toothbrush and miswak on cariogenic bacteria: A clinical study. J Contemp Dent Pract. 2004;5:105-114.
76. Machado AHS, Garcia IM, Motta ASD, Leitune VCB, Collares FM. Triclosan-loaded chitosan as antibacterial agent for adhesive resin. J Dent. 2019;83:33-39.
77. Voina C, Delean A, Muresan A, Valeanu M, Mazilu Moldovan A, et al. Antimicrobial activity and the effect of green tea experimental gels on teeth surfaces. Coatings. 2020;10:537.
78. Moslehitabar Z, Bagheri H, Rangrazi A, Faramarzi Garmroodi A, Hodjatpanah Montazeri A. Efficacy of an experimental CPP-ACP and fluoride toothpaste in prevention of enamel demineralization: An in vitro study on bovine enamel. Int J Dent. 2025;2025:5598592.