MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
SUMY STATE UNIVERSITY
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Eastern Ukrainian Medical Journal

116, Kharkivska st., Sumy 40007, Ukraine
e-mail: eumj@med.sumdu.edu.ua

eumj.med.sumdu.edu.ua
ISSN: 2663-5909 (print)/2664-4231 (online)

How to cite: Mishra A, Kumar G, Menon I, Singh A, Dash KS, Swain A. Antimicrobial Enhancement of Glass Ionomer Cement with Phytomedicine. *East Ukr Med J.* 2026;14(2):362-371. DOI: https://doi.org/10.21272/eumj.2026;14(2);362-371

ABSTRACT

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ANTIMICROBIAL ENHANCEMENT OF GLASS IONOMER CEMENT WITH PHYTOMEDICINE

Background: Glass ionomer cement (GIC) is widely used in restorative dentistry because of its ability to release fluoride, its compatibility with biological tissues, and its chemical bonding with tooth structures. However, its inherently limited antimicrobial properties make restorations susceptible to bacterial growth and the development of secondary cavities. The integration of phytomedicines – bioactive compounds derived from plants – has been identified as a promising approach to boost the antimicrobial capabilities of GIC while maintaining its mechanical integrity.

Aim: This review aims to explore and synthesize current evidence on the modification of Glass Ionomer Cement with phytomedicinal agents.

Methods: Literature search was conducted using electronic databases including PubMed and Google Scholar, focusing on articles published in the English language between 2014 and 2024. Only in vitro studies evaluating antibacterial activity as a primary outcome were included, while mechanical properties were considered when reported alongside antimicrobial testing. This review collected evidence from in vitro studies evaluating GIC modified with herbal extracts such as *Azadirachta indica* (neem), *Curcuma longa* (turmeric), *Thymus vulgaris* (thyme), Triphala, propolis, *Salvadora persica* (miswak), and *Acacia nilotica* (babool). The antibacterial activity against cariogenic microorganisms, primarily *Streptococcus mutans* and *Lactobacillus* species, and compressive strength were assessed.

Results: Most modified GIC formulations demonstrated enhanced antibacterial activity with surface antimicrobial characteristics compared with conventional GIC. Several

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studies also reported preserved or improved compressive strength at optimal extract concentrations.

Conclusion: Phytomedicine-infused GIC shows promise as a biocompatible and cost-effective restorative material. However, further standardization and in vivo studies are required to validate clinical efficacy and safety.

Keywords: Glass ionomer cement; Antimicrobial; Phytomedicine.

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INTRODUCTION

The continuous evolution of dental science is often driven by necessity, as emerging clinical challenges, shifting patient expectations, and technological advancements collectively shape the development of new materials and techniques [1]. Despite significant progress in dental care, dental caries remains one of the most persistent and prevalent oral health issues worldwide, particularly in the realm of public health [2].

Dental caries is a multifactorial disease primarily caused by the metabolic activities of acidogenic and aciduric bacteria. Among these, Streptococcus mutans, a Gram-positive bacterium, plays a central role in the initiation and progression of carious lesions. It adheres to the tooth surface, metabolizes dietary carbohydrates (especially sucrose), and produces organic acids that lower the pH in the oral environment [3]. This acidic environment disrupts the dynamic balance between demineralization and remineralization, favoring the loss of mineral content from enamel and dentin [4]. In more advanced stages, Lactobacillus species significantly contribute to the development of deep dentinal and root caries.

As the infection progresses, it can extend into the pulp, eliciting inflammatory responses in both the pulpal and periodontal tissues. In line with the principles of Minimal Intervention Dentistry (MID), carious lesion management now emphasizes conserving sound tooth structure rather than complete removal [5, 6]. This clinical philosophy advocates for the selective excavation of infected dentin, which is heavily colonized and irreversibly demineralized, while preserving affected dentin, which may retain potential for remineralization. This approach minimizes trauma to the pulp-dentin complex and enhances the longevity of restorative treatments [7]. Concurrently, the evolution of restorative dental materials has shifted toward the use of biologically compatible, functionally active substances. One such material that has gained widespread acceptance is Glass Ionomer Cement (GIC) [8, 9].

GICs belong to the category of acid-base reaction-based materials, comprising fluor aluminosilicate glass powder and polyalkenoic acid. According to the International Organization for Standardization (ISO), they are officially classified as Glass Polyalkenoate Cements, though the term "Glass Ionomer Cement" remains widely used in clinical practice and scientific literature [10, 11]. These materials are particularly valued for their chemical adhesion to enamel and dentin, fluoride ion release, thermal compatibility with tooth structures, and biocompatibility [12].

One of the defining characteristics of GICs is their ability to release fluoride ions, which confer anti-cariogenic properties by inhibiting demineralization, promoting remineralization, and modulating bacterial activity [13]. Research has shown that the amount of fluoride released – typically around 10 parts per million (ppm) in the first 48 hours – is insufficient to maintain sustained bactericidal effects [14]. Furthermore, viable microorganisms have been found beneath GIC restorations even after extended periods, indicating that fluoride alone may not offer comprehensive antimicrobial protection. These limitations have prompted efforts to enhance the bioactivity of GICs, particularly their antimicrobial capacity, through material modification. One promising approach involves incorporating phyto therapeutic agents – bioactive compounds derived from medicinal plants [15, 16].

Phytomedicine, or herbal medicine, involves using various plant parts (leaves, roots, bark, seeds) and their extracts for therapeutic purposes. Historically, it represents one of the earliest forms of human medical practice. Although the advent of synthetic pharmaceuticals led to a decline in herbal treatments, recent years have seen a resurgence in interest, driven by the desire for natural, non-toxic, and resistance-free alternatives to conventional antimicrobials [17,18]. The incorporation of herbal extracts into GIC formulations represents an innovative approach to overcoming the limitations of traditional fluoride-based restoratives

[19]. These Phyto-modified GICs aim to provide enhanced antimicrobial action without compromising the fundamental physical or mechanical properties of the material. Furthermore, they may help prevent secondary caries, a common cause of restoration failure, and support long-term oral health maintenance.

This review aims to explore and synthesize current evidence on the modification of Glass Ionomer Cement with phytomedicinal agents. It seeks to highlight the antimicrobial potential, mechanisms of action, clinical implications, and future prospects of herbally modified GICs, thereby contributing to the broader discourse on developing bioactive, biocompatible restorative materials for modern dentistry.

MATERIALS AND METHODS

A thorough literature search was conducted using various combinations of keywords, including anti-infective agents, antimicrobial agents, antibacterial agents, natural, plant-based, Glass Ionomer Cements, and Modified Glass Ionomer Cements. This search was carried out across electronic databases PubMed and Google Scholar, with a focus on publications in the English language.

The inclusion criteria covered in-vitro studies that primarily explored the antibacterial activity and surface antimicrobial characteristics of Glass Ionomer Cement after the incorporation of plant-derived antibacterial agents. Evaluating Physical properties was considered when reported alongside antibacterial in vitro studies, to determine whether the addition of herbal agents affected the mechanical integrity necessary for effective clinical use in the oral cavity. Studies were excluded if they investigated other types of modified GICs or dental materials not related to plant-based antimicrobial modifications. The screening process began with an initial evaluation based on the title, abstract, and keywords, followed by a detailed review of the full-text articles. Only studies published within the last 10 years (2014–2024) were considered for inclusion. After applying the selection criteria and conducting a thorough assessment, relevant in vitro studies evaluating antibacterial activity of phytomedicine- modified glass ionomer cements were included in this review.

GLASS IONOMER CEMENTS

Glass ionomer cements (GICs), first developed by Wilson and Kent around 1972, have become essential in restorative dentistry. Glass ionomer cements are composed of a fluor aluminosilicate glass powder and an aqueous solution of polyalkenoic acids. The powder phase typically includes silica, alumina, aluminium fluoride, calcium fluoride, sodium fluoride, aluminium phosphate, and radiopaque elements such as strontium, barium, or zinc oxide. The liquid phase consists of polyacrylic acid copolymers, tartaric acid to regulate working and setting time, and water, which facilitates the acid–base reaction and hydration of reaction products.

These materials are available in both manually mixed and encapsulated formulations and serve various functions, including as restorative agents, luting cements, cavity liners, and bases. GICs are esteemed for their distinctive properties, particularly their ability to form chemical bonds with dental hard tissues and their sustained fluoride release and recharge capability, which aids in caries prevention. Although the International Organization for Standardization (ISO) officially designates them as “glass polyalkenoate cements,” the term “glass ionomer” remains widely recognized and commonly used within the dental profession.

RECENT ADVANCEMENTS AND MODIFICATIONS OF GIC

GIC WITH PHYTOMEDICINE

Phytomedicine, alternatively referred to as herbal or botanical medicine, constitutes the scientific discipline focused on the utilization of plants and their extracts for therapeutic purposes. This field encompasses the rigorous investigation of plant- derived remedies, including their active constituents, pharmacological characteristics, and clinical applications. The integration of Phytomedicine with Glass Ionomer Cement (GIC) involves the incorporation of plant extracts or their active compounds into GIC to augment its antimicrobial properties and enhance dental treatment outcomes. Table 1 illustrates the Effect of Phytomedicine modified GIC.

CURCUMA LONGA WITH GIC

Turmeric (Curcuma longa), commonly referred to as "HALDI" in Indian households, is a perennial herb. In the study conducted by Prabhakar AR, turmeric was incorporated in powder form into glass ionomer cement (GIC), and the results of this in vitro investigation indicated that experimental GICs containing turmeric effectively inhibit Streptococcus mutans, the primary bacterium responsible for dental caries. The addition of turmeric at a concentration of 1 w/w% proved more efficacious without adversely affecting the physical properties of the GIC [1].

Table 1. Comparative antimicrobial efficacy and mechanical performance of phytomedicinemodified glass ionomer cements

Author (Year)	Modified GIC (Phytomedicinal Agent)	Target Microorganisms	Antibacterial Action	Effect on Mechanical Properties	Effective / Optimal Concentration	Clinical Interpretation
Prabhakar A R, Yavagal Chandrashekar M, Karuna YM, Mythri P. (2014) [1]	Curcuma longa modified GIC	Streptococcus mutans	Evaluated against S. mutans; significant inhibition observed	No alterations in physical properties including shear bond strength, microleakage, setting time, or compressive strength	1% concentration	Antibacterial enhancement with preserved mechanical integrity
Shahriar Shahriari, Mehrdad Barekatain, Mohammad Ali Shahtalebi, Shirin Zahra Farhad (2019) [2]	Salvia officinalis modified GIC	S. mutans, Lactobacillus	Dose- dependent antibacterial activity	Mechanical properties of GIC remained unchanged	0.75–1.25% effective; 0.5% ineffective	Effective antibacterial action without mechanical compromise
Paulraj J & Nagar P (2020) [3]	Triphala and Propolis modified GIC	S. mutans, Lactobacillus	Highest antimicrobial activity in both modified groups	Physical and mechanical characteristics not evaluated	Comparable efficacy in both groups	Antibacterial benefit; mechanical impact not assessed
Isabelle C. Pinto, aJanaínaB. Seibert, Luciano S. Pinto, Vagner R. Santos (2020) [4]	Brazilian pepper extract (BPE) modified GIC	S. aureus, S. mutans, A. actinomy-cetemcomitans, C. albicans	Broad- spectrum antimicrobial activity	Compressive strength did not significantly differ from conventional GIC; non-cytotoxic	Effective at non-toxic concentrations	Broad antimicrobial effect with preserved strength
Lamia Singer , Gabriele Bierbaum,Katja Kehl,Christoph Bouraue (2020) [6]	Salvadora persica, Olea europaea, Ficus carica with 0.5% CHX-GIC	S. mutans, Micrococcus luteus	Enhanced antimicrobial activity in all modified groups	No significant difference except highest concentration showing increased strength	Higher extract concentration more effective	Antimicrobial enhancement with mechanical stability
Michelle Mazziero Macedo Chiode Jefferson de Souza Silva, Gabriel Peres Colonello, Ivana Barbosa Suffredini, Fernanda Kabadayan, Cintia Helena Coury Saraceni (2022) [8]	Dioscorea altissima extract modified GIC	Streptococcus mutans	Enhanced antibacterial efficacy, greater with laser activation	No effect on compressive strength	More effective with photo-dynamic therapy	Antibacterial enhancement with preserved strength
Mayada Said Sultan, Yasser Abdelaziz Abed (2022) [9]	Rosmarinus officinalis modified GIC	Streptococcus mutans	Highest antibacterial activity at 4% concentration	4% concentration showed highest compressive strength	4% concentration	Dual antibacterial and mechanical benefit
A.S Pavithra1, Jessy Paulraj, S. Rajeshkumar, Subhabrata Maiti(2023) [11]	Thymus vulgaris (thyme) modified GIC	S. mutans, Lactobacillus	Improved antibacterial activity against S. mutans	No significant changes in compressive strength	All modified groups effective	Antimicrobial gain without strength compromise
Kamala Devi, Jessy Paulraj, Rinki S George, Rajeshkumar Shanmugam, Subhabrata Maiti (2024) [15]	Swertia chirayita and Terminalia arjuna modified GIC	S. mutans, Lactobacillus	Significant antimicrobial activity in all modified groups	No statistically significant changes in compressive strength	Both extracts effective	Antimicrobial gain with mechanical stability

Author (Year)	Modified GIC (Phytomedicinal Agent)	Target Microorganisms	Antibacterial Action	Effect on Mechanical Properties	Effective / Optimal Concentration	Clinical Interpretation
Kamala Devi, Jessy Paulraj, Rajeshkumar Shanmugam, Subhabrata Maiti (2024) [16]	Miswak (Salvadora persica) infused GIC	S. mutans, Lactobacillus	Significant antibacterial enhancement	Higher concentration groups showed reduced strength	Antibacterial potency increased with concentration	Antibacterial benefit with mechanical trade- off
Jessy Paulraj, jeyashreeT, Yuvashree CS, Rajeshkumar Shanmugam, Subhabrata Maiti (2024) [17]	Acacia nilotica enriched GIC	S. mutans, Lactobacillus	Significant antimicrobial activity in all modified groups	Group III showed improved compressive strength	Higher concentration more effective	Antimicrobial enhancement with improved strength
Aswin Jaykumar Raj, Jessy Paulraj, Karthik V, Rajeshkumar Shanmugam, Subhabrata Maiti (2024) [18]	Neem and Lemongrass modified GIC	S. mutans, Lactobacillus	Neem is effective against both S. mutans and Lactobacillus. Lemongrass is effective only against S. mutans	No significant change in compressive strength	Neem effective at all concentrations	High for neem; moderate for lemongrass
Marwa Mohammed Abd Eltwab, Mohammed Moustafa Shalaby, Eman Hamdy Mohammed, Hanaa Farouk Mahmoud (2024) [19]	Aloe vera and Salvadora persica modified GIC	Streptococcus mutans	Significant antibacterial enhancement	Highest DTS at 1:1 ratio	Optimal at 1:1.5 ratio	Synergistic antibacterial and mechanical benefit

SALVIA OFFICINALIS MODIFIED GIC

Salvia officinalis, commonly known as sage, is a perennial evergreen herb native to the Mediterranean region and has also been established in regions such as Iran. The extract obtained from S. officinalis demonstrates a variety of pharmacological activities, including antimicrobial, analgesic, anti-inflammatory, and antioxidant properties. Research has indicated that incorporating S. officinalis extract into the powder phase of conventional glass ionomer cement (GIC) results in a modified dental material that can exert direct antibacterial effects against key cariogenic microorganisms. Moreover, the antibacterial efficacy of this modified GIC has been shown to be dose-dependent [2].

TRIPHALA MODIFIED GIC

Triphala, a traditional Ayurvedic formulation, consists of three medicinal plants: *Terminalia chebula, Terminalia bellerica,* and *Phyllanthus emblica*, each recognized for its therapeutic properties. *Terminalia chebula*, the primary component, demonstrates anticariogenic activity by inhibiting sucrose-mediated bacterial adhesion, thereby diminishing the pathogenicity of cariogenic microorganisms. *Terminalia bellerica* contains tannic acid, which adheres to bacterial cell surfaces, resulting in protein denaturation and cell lysis. Consequently, the incorporation of Triphala into glass ionomer cement enhances its antimicrobial properties [3].

PROPOLIS MODIFIED GIC

Propolis, a natural resinous material valued since ancient times for its antioxidant and healing qualities, has been a mainstay in traditional medicine. Studies reveal that glass ionomer cement (GIC) containing a 50% ethanolic extract of propolis results in a more pronounced decrease in viable bacterial numbers compared to versions with just 25%. This discovery implies that GIC enhanced with propolis might be effective in lowering the risk of secondary caries [3].

BRAZILIAN PEPPER EXTRACT (BPE) MODIFIED GIC

Schinus terebinthifolius Raddi, commonly known as Brazilian pepper or Aroeira, is a medicinal plant from the Anacardiaceae family, native to Brazil. The antimicrobial potential of its ethanolic extract (BPE), both alone and incorporated into glass ionomer cement (GIC-BPE), was evaluated against key oral pathogens, including Streptococcus aureus, Streptococcus mutans, Aggregatibacter actinomycetemcomitans, and Candida albicans (ATCC 18804). Findings demonstrated that GIC-BPE exhibits antimicrobial activity without cytotoxic effects on human fibroblasts, indicating its promise as a potential alternative agent for endodontic applications [4].

SALVADORA PERSICA, OLEA EUROPAEA, AND FICUS CARCIA WITH 0.5% CHLOROHEXIDINE-MODIFIED GIC (CHX-GIC)

Salvadora persica, an evergreen shrub belonging to the Salvadoraceae family, is extensively distributed across regions from India and Nepal to Pakistan, Egypt, and parts of Africa. Ficus carica, a species within the Moraceae family, is among the earliest cultivated fruit species and is recognized for its antioxidant, anti-inflammatory, antibacterial, and antiviral properties. Olea europaea similarly exhibits significant antioxidant and antimicrobial effects. A combination of these plant extracts (PE) was integrated into the liquid component of glass ionomer cement (GIC) in three ratios: 1:1, 2:1, and 1:2. The modified cements were evaluated against unmodified GIC and 0.5% chlorhexidine-GIC (CHX-GIC) using agar diffusion assays targeting Streptococcus mutans and Micrococcus luteus. All extract-modified GICs demonstrated significantly enhanced antimicrobial activity against S. mutans, with the highest extract concentration exhibiting efficacy comparable to that of CHX-GIC. An increased inhibition of M. luteus was also noted, albeit only in the group with the highest extract concentration [6].

DIOSCOREA ALTISSIMA EXTRACT (EB) WITH GIC

Adding Dioscorea altissima extract (EB), which is high in chlorophyll, to glass ionomer cement (GIC) could be a good alternative to methylene blue (MB) for killing bacteria that cause cavities. This study looked at how well EB-modified GIC, when used with laser light, worked against Streptococcus mutans. There were eight test groups: G1–GIC; G2–GIC + Laser; G3–GIC/EB; G4–GIC/EB + Laser; G5–GIC + MB; G6–GIC + aPDT; G7–GIC/EB + MB; and G8–GIC/EB + aPDT. Tests showed that G6 (GIC + aPDT) stopped the most bacteria ($p < 0.001$). Groups G4, G5, G7, and G8 also stopped bacteria well, with no big differences between them ($p > 0.05$). Groups G2 and G3 were the least effective. The results suggest that EB makes GIC better at killing bacteria, and using a laser makes it even more effective against S.mutans [8].

ROSMARINUS OFFICINALIS L. MODIFIED GIC

Rosmarinus officinalis L. (rosemary), a member of the Lamiaceae family, is a medicinal plant renowned for its antioxidant, antimicrobial, antifungal, and anti-inflammatory properties. Its extract has proven effective in reducing bacterial biofilm viability and has been incorporated into oral hygiene products for plaque control. In this study, sixty specimens were divided into three groups: Group 1 (unmodified glass ionomer cement, GI), Group 2 (2% rosemary-extract-modified GIC), and Group 3 (4% rosemary-extract- modified GIC). Antibacterial activity against Streptococcus mutans was assessed using the disc diffusion method after 48 hours. The results indicated that Group 3 exhibited the most significant antimicrobial effect [9].

THYME-MODIFIED GIC

Thymus vulgaris, commonly known as thyme, is a small, aromatic herb frequently utilized in both culinary and medicinal contexts. It contains essential oils with antimicrobial and healing properties. In this research, dried thyme leaves were combined with standard glass ionomer cement (GIC) in three distinct ratios: 2:1:1 (Group I), 3:1:2 (Group II), and 3:2:1 (Group III), while Group IV remained unchanged. The antibacterial effectiveness was evaluated against Streptococcus mutans and Lactobacillus. The GIC groups mixed with thyme showed improved antibacterial activity against S. mutans without losing strength. However, there was no significant difference observed for Lactobacillus. This indicates that thyme-enhanced GIC is more effective at killing bacteria than regular GIC [11].

SWERTIA CHIRAYITA (S. CHIRAYITA) AND TERMINALIA ARJUNA (T. ARJUNA) MODIFIED GIC

Terminalia arjuna (T. arjuna), a species within the Combretaceae family, is indigenous to India and neighbouring regions such as Burma, Sri Lanka, and Mauritius. The bark and leaves of T. arjuna are abundant in bioactive compounds, including glycosides, flavonoids, and tannins, which are recognized for their cardioprotective, anti- inflammatory, antibacterial, and antimicrobial properties. Similarly, Swertia chirayita (Chirata) is characterized by high concentrations of phytochemicals in its leaves, stems, and roots, which contribute to its antimicrobial efficacy. This study assessed the antimicrobial potential of glass ionomer cement (GIC) modified with extracts from T. arjuna and Chirata using the minimum inhibitory concentration (MIC) assay against Streptococcus mutans and Lactobacillus. Both modified groups exhibited significantly enhanced antimicrobial activity compared to unmodified GIC. T. arjuna and Chirata- modified GICs were more effective against S. mutans, while Chirata demonstrated superior activity against Lactobacillus. Importantly, the incorporation of these extracts did not compromise the compressive strength of GIC, indicating their suitability for augmenting its antimicrobial properties [15].

MISWAK-INFUSED GIC

Salvadora persica, commonly recognized for its application in traditional oral hygiene as miswak, is predominantly located in East Asia and West Africa. Miswak refers to chewing sticks derived from various plant sources, with S. persica being among the most frequently utilized. Extracts from this plant have been integrated into oral care products such as toothpaste and mouthwash due to their significant antibacterial properties against key oral pathogens, including Candida albicans, Streptococcus mutans, Aggregatibacter actinomycetemcomitans, Lactobacillus acidophilus, Actinomyces naeslundii, and Porphyromonas gingivalis. Rich in minerals such as fluoride, phosphate, and calcium – constituents of dental hydroxyapatite – S. persica contributes to enhanced oral health. In this study, S. persica extract was incorporated into glass ionomer cement (GIC) in three ratios: Group I (2:1:1), Group II (3:1:2), and Group III (3:2:1), with Group IV serving as the control (unmodified GIC). Antimicrobial testing against S. mutans and Lactobacillus demonstrated significantly improved activity in all modified groups compared to the control ($p < 0.05$), with higher extract concentrations resulting in greater efficacy [16].

ACACIA NILOTICA ENRICHED GIC

Acacia nilotica, commonly referred to as babool and known by various regional names such as kikar, babul, and Acacia arabica, is abundant in antioxidant phenolic compounds, notably condensed tannins and phlobatannins. These bioactive constituents are responsible for its significant antibacterial and antiplaque properties. In this study, Acacia nilotica extract was integrated into conventional glass ionomer cement (GIC) in three ratios: Group I (2:1:1), Group II (3:1:2), and Group III (3:2:1), with Group IV serving as the unmodified control. Antibacterial assays against Streptococcus mutans and Lactobacillus demonstrated significantly enhanced activity in all modified groups compared to the control ($p < 0.05$), suggesting the potential of Acacia-modified GIC as an effective restorative material [17].

NEEM AND LEMONGRASS-MODIFIED GIC

Azadirachta indica (neem) from the Meliaceae family and Cymbopogon citratus (lemongrass) from the Poaceae family are medicinal plants renowned for their rich phytochemical profiles and therapeutic properties. In this study, extracts from neem and lemongrass were incorporated into conventional glass ionomer cement (GIC) at concentrations of 0.5%, 1%, and 2%. Group I comprised neem-modified GIC, Group II consisted of lemongrass-modified GIC, and Group III served as the unmodified control. The antimicrobial activity was assessed using the MIC assay against Streptococcus mutans and Lactobacillus. Neem-modified GIC demonstrated significantly enhanced antimicrobial activity against both bacterial strains at all concentrations. In contrast, lemongrass exhibited significant efficacy only against S. mutans. Overall, neem showed superior antimicrobial performance compared to lemongrass ($p < 0.05$) [18].

ALOE VERA (AVE) AND SALVADORA PERSICA(SPE) WITH GIC

An alcoholic extract of Aloe Vera (AVE) and an alcoholic extract of Salvadora persica (SPE) were prepared. Subsequently, the two extracts were combined in equal proportions by weight (1 AV: 1 SP) to formulate a Plant Extract (PE). This PE was then incorporated into the glass ionomer liquid. The antimicrobial activity against Streptococcus mutans (SM) was evaluated using the agar well diffusion assay method. The highest antimicrobial activity was observed at a ratio of 1 Glass Ionomer Liquid to 1.5 Plant Extract. Therefore, the Plant Extract significantly enhanced the antimicrobial activity of the Glass Ionomer Cement (GIC) against Streptococcus mutans [19].

DISCUSSION

The review revealed various plant extract added to Glass Ionomer Cement. Various in vitro studies render that there was a significant antimicrobial efficacy in all the modifications of plant extract modified GIC. A variety of methods such as agar diffusion test, spectrophotometry, methyl thiazolyl tetrazolium (MTT) assays, scanning electron microscopy (SEM), broth culture tests, and MBC (minimum bactericidal concentration) and MIC (minimum inhibitory concentration) determination, were used to determine the antibacterial effects. This makes the comparison of the results across studies difficult. The use of varied strains of bacteria further complicates the comparisons, although S. mutans has been frequently used [1].

The incorporation of plant-derived bioactive compounds into glass ionomer cement (GIC) marks a notable advancement in creating restorative materials with improved antimicrobial properties. This review compiles findings from various in vitro studies that explore the antibacterial potential of different herbal extracts added to traditional GIC formulations. These extracts include Curcuma longa, Salvia officinalis, Triphala, Propolis, Brazilian Pepper, Salvadora persica, Olea europaea, Ficus carica, Dioscorea altissima, Rosmarinus officinalis, Thymus vulgaris, Swertia chirayita, Terminalia arjuna, Miswak, Acacia nilotica, Neem, Lemongrass, and Aloe vera. The studies consistently show that incorporating plant extracts significantly boosts the antimicrobial effectiveness of GIC against Streptococcus mutans, Lactobacillus spp., and other oral pathogens, while generally maintaining or enhancing mechanical strength.

Among the studied agents, Neem (Azadirachta indica) stood out as a highly effective antibacterial enhancer when integrated into GIC [2]. Its wide-ranging antimicrobial activity against both S. mutans and Lactobacillus at various concentrations, without compromising compressive strength, underscores its potential as a dependable bioactive additive. In contrast, Lemongrass exhibited selective antimicrobial activity – effective against S. mutans but not Lactobacillus – highlighting the importance of species-specific effectiveness in material design [18]. Similarly, Curcuma longa, at a 1% concentration, effectively increased the antibacterial action and fluoride release of GIC without affecting key physical properties such as microleakage, bond strength, or setting time [1]. This finding emphasizes the advantage of enhancing both therapeutic and preventive properties within a single restorative material.

Salvia officinalis and Rosmarinus officinalis also showed significant antimicrobial effects against cariogenic bacteria, with the latter achieving the highest antibacterial efficacy at a 4% concentration while simultaneously increasing compressive strength [2, 9]. These results confirm the dual benefit of certain extracts in enhancing both biological and mechanical outcomes. Triphala and Propolis, when used individually, demonstrated comparable antimicrobial activity, although further research is needed to assess their impact on the mechanical and structural performance of GICs. Similarly, Dioscorea altissima extract not only improved antibacterial action against S. mutans but also showed promise as a photosensitizer for photodynamic therapy (PDT), especially when combined with laser activation.

The addition of Swertia chirayita and Terminalia arjuna exhibited strong antimicrobial activity against both S. mutans and Lactobacillus, with no significant change in compressive strength [15]. These findings suggest their potential as effective adjuncts in restorative materials, particularly where recurrent caries is a concern. Miswak-modified GIC demonstrated concentration-dependent improvements in antimicrobial performance [16]. However, higher concentrations negatively affected mechanical strength in some groups, indicating a trade-off that needs optimization. Similarly, while Acacia nilotica enhanced antibacterial activity in all modified groups, Group III showed a statistically significant improvement in mechanical performance, supporting its promise as both a therapeutic and structurally compatible additive. Brazilian pepper extract (BPE) and combinations involving Salvadora persica, Olea europaea, and Ficus carica demonstrated antimicrobial efficacy against a broader range of oral pathogens, including Candida albicans, S. aureus, and A. actinomycetemcomitans. These extracts also maintained favourable compressive strength, suggesting that multi-component plant formulations may offer broad-spectrum antimicrobial activity while preserving essential physical properties. The combination of Aloe vera with S. persica in GIC notably enhanced antimicrobial activity at optimal levels, with certain subgroups showing the greatest diametral tensile strength. This underscores the effectiveness of synergistic plant extract combinations in improving both the biological and mechanical properties of GIC.

The studies generally indicate a positive link between plant extract concentration and antimicrobial effectiveness, although finding the right balance is crucial to prevent compromising physical properties. Most of the modifications reviewed retained satisfactory mechanical performance, but higher concentrations of miswak and some combinations showed variations, highlighting the importance of optimizing concentrations in future formulations. Hence, Future research should prioritize the development of standardized experimental protocols, the optimization of extract concentrations, and the implementation of rigorously designed in vivo and clinical studies. These efforts are essential to validate the biological safety, long-term durability, and clinical efficacy of phytomedicine-modified glass ionomer cements.

LIMITATIONS

There is considerable heterogeneity across studies regarding the phytomedicinal agents used, extraction methods, concentrations incorporated into glass ionomer cement, bacterial strains tested, and antimicrobial assessment techniques. This diversity restricts direct comparison of outcomes and the identification of optimal formulations. Additionally, all included investigations were in vitro studies, which do not replicate the complex biological and mechanical conditions of the oral cavity. Most studies relied on mono-species bacterial models, predominantly Streptococcus mutans, and long-term outcomes such as the durability of antimicrobial activity, fluoride release kinetics, cytocompatibility, and aging effects were insufficiently explored.

CONCLUSION

The integration of herbal extracts into glass ionomer cement represents a promising approach for the development of multifunctional restorative materials with enhanced antibacterial properties. Most modifications have demonstrated significant antimicrobial efficacy against common oral pathogens without negatively impacting mechanical performance. However, the variability in response across bacterial species, extract types, and concentrations underscores the necessity for standardization and further in vivo studies. Future research should prioritize long-term clinical evaluations, cytocompatibility testing, and the optimization of extract concentrations to ensure both therapeutic efficacy and structural integrity of these novel bioactive materials.

ETHICAL CONSIDERATIONS

The study was conducted without involving human subjects.

AUTHOR CONTRIBUTIONS

All authors substantively contributed to the drafting of the initial and revised versions of this paper. They take full responsibility for the integrity of all aspects of the work.

FUNDING

None.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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Received: 27.10.2025

Accepted for publication: 28.01.2026

Published: 23.06.2026