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A SYSTEMATIC REVIEW ON: ORAL GEL INFUSED WITH PHYLLANTHUS EMBLICA LINN AND CURCUMA LONGA BASED ON NATURAL HERB FOR DENTAL GUM CARE SOLUTION

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ABSTRACT

The aim of the present research was to develop and assess an herbal oral gel prepared using powdered extracts of *Phyllanthus emblica* Linn and rhizomes of *Curcuma longa* Linn for dental health management. Traditional medicine plays a vital role in cultural practices and is widely recognized for its contributions to health care in many parts of the world. *Phyllanthus emblica* (commonly known as Indian gooseberry or amla) has shown promising potential in preventing dental caries by inhibiting the growth of cariogenic bacteria such as *Streptococcus mutans*. It also helps in reducing plaque formation and stimulating saliva secretion, which are essential for maintaining oral hygiene. The presence of bioactive compounds such as vitamin C and tannins enhances its anti-cariogenic properties, suggesting its possible application in oral care products like mouth rinses and chewing gums. Similarly, turmeric (*Curcuma longa*) possesses strong anti-inflammatory, antibacterial, antioxidant, virucidal, and antimutagenic activities. It is rich in diverse phytoconstituents, including curcumin, de-methoxy curcumin, eugenol, tannins, alkaloids, saponins, terpenoids, and curcumol, which contribute to its therapeutic value. The findings of this study indicated that the herbal gel formulation prepared from *Phyllanthus emblica* and turmeric extracts exhibited favorable physicochemical characteristics and demonstrated effectiveness in managing common dental problems like dental plaque.

KEYWORD: Oral Infused gel, Hydrogel, Curcuma Longa gel, Phyllanthus Emblica Linn, Nanoparticle oral gel, Dental Care Gel, Mouth Care Preparation Gel.

1. INTRODUCTION

Dental plaque is a complex biofilm composed of microorganisms embedded within an extracellular matrix. The predominant species include *Streptococcus mutans*, along with anaerobic bacteria such as *Actinobacteria* and *Fusobacterium*, often occurring in mixed microbial communities. Accumulation of plaque can eventually mineralize into calculus and contribute to several chronic oral conditions, including gingivitis and periodontitis.[1,2]

Studies have highlighted that untreated plaque is not limited to oral complications but also elevates the risk of systemic diseases such as atherosclerosis and myocardial infarction, establishing a strong association between oral health and cardiovascular well-being. Research further indicates that respiratory pathogens can also be harbored within dental plaques, particularly in individuals with chronic lung diseases.[3]

Analysis of the plaque microbiome has revealed approximately 1,372 operational taxonomic units (OTUs), reflecting its significant role in influencing both health and disease states. Therefore, controlling dental plaque is considered a critical approach in preventing the onset of chronic systemic disorders. Supporting this, data from Taiwan's National Health Insurance (NHI) reported that more than half (around 69.59%) of dental care utilization was linked to the treatment of dental caries—a direct outcome of persistent plaque accumulation.[4]

Plaque management and prevention are primarily achieved through mechanical approaches, such as maintaining good oral hygiene practices, and chemical approaches, including the use of antiseptics or disinfectants like chlorhexidine gluconate. Advances in dental care have also introduced technologies such as dental implants, laser-based devices, and innovative instruments to combat plaque-related conditions like dental caries. In addition, researchers have explored hydrogels with antibacterial, re-mineralizing, and tissue-regenerative properties as potential solutions for plaque control. Nanoparticle-based formulations with antimicrobial activity against oral pathogens have also been investigated for their effectiveness in biofilm prevention.[5]

The core strategy of most plaque-prevention methods is centered on the use of anti-biofilm agents that inhibit microbial colonization and biofilm development on tooth surfaces. Conventional treatment of dental caries often involves antimicrobial agents such as β-lactam antibiotics, broad- spectrum tetracyclines, macrolides, fluoride, quaternary ammonium salts, and antimicrobial peptides. However, excessive and prolonged use of these agents can contribute to side effects and the emergence of resistant bacterial strains, highlighting the need for safer and more sustainable alternatives.

In this context, natural plant-based therapeutics have gained attention. *Phyllanthus emblica* (Indian gooseberry) and *Curcuma longa* (turmeric) are widely available medicinal plants known for their anti-plaque potential. Their activity is attributed to antibacterial effects against cariogenic bacteria, stimulation of salivary secretion, and anti-inflammatory actions, while also lowering the risk of antimicrobial resistance.[6]

Curcumin, the major bioactive compound of turmeric, exhibits strong antibacterial activity against *Streptococcus mutans* and is also recognized for its anti-inflammatory and anticancer properties, both as a standalone agent and in combination therapies. Similarly, ethanolic extracts of *Phyllanthus emblica* have shown significant inhibitory effects on cariogenic bacteria, particularly *S. mutans*. Being a natural source of vitamin C, along with essential nutrients such as pectin, calcium, iron, and phosphorus, *P. emblica* demonstrates a wide range of pharmacological benefits, including

antioxidant, antibacterial, antiviral, and hypolipidemic activities.[7]

Despite their wide range of medicinal benefits, natural products often face limitations such as poor permeability through dental tissues, which reduces their therapeutic effectiveness. Issues like slow release and restricted penetration hinder their optimal activity. These challenges can be addressed through the incorporation of nanoparticles in the gel as advanced drug delivery carriers. To overcome these barriers, we propose the formulation of an oral infused gel with nanoparticle-based systems for enhanced delivery and sustained action of herbal extracts.

2. Dental Plaque

2.1 Introduction

Dental plaque is a soft, sticky biofilm that forms on the surface of teeth and along the gumline. It is composed of microorganisms, mainly bacteria, embedded in an extracellular polymeric matrix of salivary proteins, polysaccharides, and microbial by-products. Plaque is the primary etiological factor for common oral diseases such as **dental caries, gingivitis, and periodontitis**. If not controlled, it may also contribute to systemic diseases, including cardiovascular and respiratory disorders, due to microbial dissemination.[8,9,10]

2.2 Formation of Plaque

The development of dental plaque occurs in **sequential stages shown in (fig 1)**:

I. Pellicle Formation

- Within minutes after tooth cleaning, a thin acellular layer known as the **acquired pellicle** forms on tooth surfaces.
- It is mainly composed of glycoproteins, enzymes, and antibodies derived from saliva.
- This pellicle provides binding sites for microorganisms.

II. Initial Bacterial Colonization

- Early colonizers such as *Streptococcus sanguinis*, *Streptococcus mutans*, and *Actinomyces* species attach to the pellicle via adhesins.
- These bacteria multiply and start producing extracellular polysaccharides, strengthening adhesion.

III. Secondary Colonization and Biofilm Maturation

- Other microorganisms such as *Fusobacterium nucleatum*, *Veillonella*, and *Porphyromonas* species join the biofilm through co-aggregation.
- The microbial community grows, forming a structured biofilm with water channels that allow nutrient and waste exchange.

IV. Mature Plaque Formation

- After 24–48 hours, plaque becomes more complex and pathogenic.
- Anaerobic bacteria dominate, producing acids and toxins that cause demineralization of enamel and inflammation of gingiva.
- If mineralized by calcium and phosphate from saliva, plaque hardens into **calculus (tartar)**, which is more difficult to remove.

2.3. Types of Dental Plaque

Dental plaque is broadly classified based on its **location**, **composition**, and **maturation stage.**[11,12] Understanding these types is important for diagnosis and treatment planning **shown in (fig. 2)**

2.3.1. Based on Location

I. Supragingival Plaque

- Found **above the gumline**, on the exposed surface of teeth.
- Mostly composed of aerobic and facultative anaerobic bacteria such as *Streptococcus mutans* and *Actinomyces*.
- Strongly associated with **dental caries**.
- Can be removed easily with brushing and flossing.

II. Subgingival Plaque

- Located **below the gumline**, within the gingival sulcus or periodontal pocket.
- Contains mostly anaerobic and pathogenic bacteria like *Porphyromonas gingivalis* and *Fusobacterium nucleatum.*
- Strongly linked to **gingivitis and periodontitis**.
- More difficult to remove; requires professional scaling.

2.3.2. Based on Maturation Stage

I. Early Plaque

- Forms within 24 hours after tooth cleaning.
- Dominated by gram-positive bacteria (*Streptococcus* species).
- Usually not harmful if controlled.

II. Mature Plaque

- Forms after 48–72 hours.
- Becomes more complex, dominated by gram-negative anaerobes.
- Associated with gingival inflammation and disease progression.

2.3.3. Based on Microbial Composition

I. Gram-positive Plaque

- Predominant in the early stages.

- Contains streptococci and actinomyces.
- Plays a role in caries formation.

II. Gram-negative Plaque

- Seen in mature and subgingival plaques.
- Includes anaerobes such as *Prevotella*, *Porphyromonas*, and *Fusobacterium*.
- Associated with periodontal disease.

2.3.4. Other Special Types

I. Dental Calculus (Tartar)

- Mineralized plaque due to deposition of calcium and phosphate salts from saliva.
- Provides a rough surface for further plaque accumulation.
- Requires professional removal.

II. Cariogenic Plaque

- High in acid-producing bacteria (*S. mutans*, *Lactobacilli*).
- Causes demineralization of enamel leading to dental caries.

III. Periodontal Plaque

- Rich in anaerobic bacteria causing destruction of periodontal tissues.
- Major factor in gingivitis and periodontitis.

3. Dental Gel Infused with Nanoparticles

3.1 Introduction

Dental care has traditionally relied on mechanical plaque removal and chemical agents such as fluoride and chlorhexidine. However, limitations such as bacterial resistance, side effects (tooth staining, altered taste), and poor permeability of natural agents into dental tissues have encouraged the development of advanced formulations.[13,14] **Nanotechnology** has emerged as a promising approach to enhance drug delivery in dentistry. Incorporating nanoparticles into dental gels improves drug stability, permeability, bioavailability, and controlled release, thereby offering more effective plaque control and oral disease management. [15]

3.2 Definition of Gels

According to the **Indian Pharmacopoeia (I.P.)**, gels are described as homogeneous, semisolid preparations that typically consist of solutions or dispersions of one or more active pharmaceutical ingredients incorporated into suitable hydrophilic or hydrophobic bases.

The **United States Pharmacopoeia (U.S.P.)** defines a gel as a semisolid dosage form containing a dispersion of either large organic molecules or small inorganic particles within a liquid medium. In the case of inorganic gels, the particles interact to form a three-dimensional network, often compared to a "house of cards" structure, which imparts rigidity and stability to the preparation (**Shown in fig 3**).[16,17]

3.3 Classification of Gels

Gels can be categorized on the basis of **colloidal phases, type of solvent, physical characteristics, and rheological properties.**[18,19]

The major classifications are as follows:

1. **Based on Colloidal Phases**

- **Inorganic Gels (Two-phase system)**
  - Consist of a continuous liquid phase and a dispersed solid phase.
  - The particles are relatively large and form a three-dimensional network, often referred to as a "house of cards" structure.
  - Example: **Bentonite gel, Aluminium hydroxide gel.**

- **Organic Gels (Single-phase system)**
  - Consist of high-molecular-weight organic substances uniformly dispersed within a liquid phase.
  - The system is more homogenous compared to inorganic gels.
  - Example: **Carbopol gel, Tragacanth gel.**

3.4 Why Nanoparticles in Dental Gel?

- **Enhanced Penetration:** Nanoparticles can penetrate deeper into dental tissues and biofilms, increasing the efficacy of active compounds.
- **Controlled Release:** Provide sustained and slow drug release for long-lasting effects.
- **Targeted Delivery:** Can deliver antimicrobials directly to cariogenic bacteria and periodontal pockets.
- **Overcoming Drug Resistance:** Reduce the required drug dose, minimizing bacterial resistance.
- **Improved Stability:** Protect sensitive natural compounds (e.g., curcumin, vitamin C) from degradation. [20,21]

3.5 Treatment and Control of Plaque by Advanced Therapies

- **Laser and Photodynamic Therapy:** Used for plaque removal and periodontal therapy.
- **Nanoparticle-Based Delivery Systems:** Provide controlled release of antibacterial and anti-biofilm agents.

- **Probiotics:** Use of beneficial bacteria to restore healthy oral microbiota balance.
- **Herbal Formulations:** Natural products like *Phyllanthus emblica* (Amla) and *Curcuma longa* (Turmeric) show anti-plaque, anti-inflammatory, and antibacterial effects with fewer side effects. [22]

3.6 Herbal Formulation of Natural Product

3.6.1 Curcuma longa and Phyllanthus emblica

Curcuma longa Linn., commonly known as turmeric, is a perennial herb belonging to the family **Zingiberaceae**. It is widely used in Ayurveda, Siddha, and Unani systems of medicine. The rhizome of turmeric is rich in bioactive compounds that possess **antimicrobial, anti- inflammatory, antioxidant, and wound-healing as well as Dental healing properties,** making it beneficial for oral health and prevention of dental caries. [23]

Chemical Constituents of Curcuma longa are many types which is very helpful to various disease, The pharmacological activities of turmeric are mainly attributed to its diverse phytochemical profile **Curcuminoids (3–5%)** Curcumin, Desmethoxycurcumin, Bisdemethoxycurcumin, **Volatile Oils (2–7% -**Turmerone, Atlantone, Zingiberene), **Other Constituents (**Proteins, resins, carbohydrates) **Minerals** like calcium, potassium, and iron. [24]

Among these, **curcumin** is the principal bioactive compound responsible for its antibacterial, antioxidant, and anticaries properties shown in **fig 4**.

Phyllanthus emblica Linn., commonly known as **Amla or Indian Gooseberry**, belongs to the family **Phyllanthaceae**. It has been valued in Ayurveda, Unani, and Siddha medicine for centuries due to its **rejuvenating, antimicrobial, antioxidant, and anti-inflammatory properties**. In oral health, Amla plays a crucial role in **strengthening teeth, preventing caries, reducing gum inflammation, and promoting overall oral hygiene.** [25,26]

Amla fruit is one of the richest natural sources of **Vitamin C** and other phytochemicals - **Ascorbic Acid (Vitamin C)** – Enhances collagen synthesis, strengthens gums, and prevents scurvy-related gum bleeding.

There are very useful like **Polyphenols (**Gallic acid, Ellagic acid, Emblicanin A & B unique to amla), **Flavonoids (**Quercetin, Kaempferol, Rutin), **Tannins** – Provide antimicrobial and antioxidant effects, **Minerals** – Calcium, phosphorus, iron. [27]

These bioactive compounds contribute to **antibacterial, antioxidant, and healing activities** in dentistry shown in **fig 5.**

4. Mechanism of Curcuma longa and Amla Infused Gel in Plaque Removal

Curcumin and Amla extract has low water solubility and poor bioavailability when used directly. To overcome these challenges, **nanoparticle-based formulations** are developed like infused Nanoparticle gel. [28,29]

4.1. Adhesion & Penetration of Gel

- When applied to the teeth and gums, the **nanoparticle-infused gel** adheres firmly to the oral surface.
- Nanoparticles enhance penetration into **dental biofilm** (plaque layer) and ensure sustained release of bioactive compounds.
- This prolonged retention improves contact time with oral pathogens.

4.2. Antimicrobial Action

I. Curcuma longa (Curcumin)

- Curcumin disrupts the **cell membrane integrity** of *Streptococcus mutans* and *Lactobacillus*, the main cariogenic bacteria.
- It interferes with **bacterial glycolysis**, reducing acid production that causes enamel demineralization.
- Curcumin also inhibits quorum sensing, thereby preventing **biofilm maturation**.

II. Amla (Phyllanthus emblica)

- Vitamin C, tannins, and polyphenols exert **bacteriostatic and bactericidal effects**, reducing bacterial adhesion to tooth surfaces.
- Amla polyphenols form complexes with bacterial proteins, interfering with plaque formation [30].

4.3. Anti-inflammatory & Antioxidant Effect

- Curcumin blocks **COX-2 and NF-κB pathways**, reducing gum inflammation caused by bacterial toxins.
- Amla's **Vitamin C and emblicanins** scavenge free radicals, preventing oxidative damage to gingival tissues.
- Together, they promote **healthier gums and prevent gingivitis progression**.

4.4 Plaque Disruption & Detachment

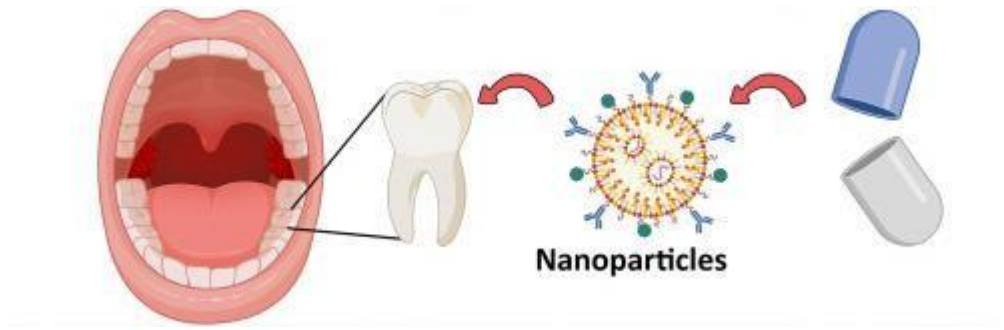
- The nanoparticle system allows deeper penetration into plaque biofilms.
- Curcumin weakens the **extracellular polysaccharide matrix**, making plaque less stable.
- Amla tannins reduce bacterial adhesion forces, helping in **detachment of plaque deposits.** [31]

4.5 Remineralization & Tissue Repair

- Amla provides **calcium and phosphorus**, aiding in enamel remineralization.
- Vitamin C enhances **collagen synthesis**, strengthening gum tissues.
- This supports natural healing of oral tissues after plaque removal.

4.6 Sustained & Targeted Action via Nanoparticles

- Nanoparticles protect active compounds from degradation (especially Vitamin C and Curcumin).
- Provide **controlled release**, ensuring prolonged antimicrobial effect.
- Enhance solubility and bioavailability, making the gel more effective than crude extracts.



5. CONCLUSION

Dental caries and plaque accumulation remain one of the most common oral health challenges worldwide, often leading to tooth decay, gingivitis, and periodontal disease. Conventional treatments such as synthetic mouth rinses and chemical gels are effective but often associated with side effects like tooth staining, altered taste sensation, or disruption of the oral microbiota. Therefore, there is a growing interest in herbal and natural alternatives that are safe, biocompatible, and effective. In this context, **Curcuma longa (Turmeric)** and **Phyllanthus emblica (Amla)** have emerged as promising agents for oral care due to their unique phytochemical composition and multifaceted biological activities.[32,33]

Curcuma longa contains curcuminoids, particularly **curcumin**, which exhibit strong **antimicrobial, anti-inflammatory, and antioxidant** properties. These effects directly target *Streptococcus mutans* and *Lactobacillus* species, the primary cariogenic bacteria responsible for plaque formation and dental caries. Additionally, curcumin reduces inflammation of the gums, alleviates oxidative stress, and assists in maintaining oral tissue health. On the other hand, Amla is one of the richest natural sources of **Vitamin C**, along with tannins, flavonoids, and polyphenols like emblicanin A and B. These compounds not only strengthen gum tissue and enhance collagen synthesis but also contribute to **antimicrobial and demineralizing effects**, thereby protecting teeth from demineralization and reducing plaque adhesion.[34,35]

Despite their potential, direct application of these herbal extracts is limited due to **poor solubility, low stability, and limited bioavailability**. This challenge is effectively overcome through **nanoparticle-based delivery systems**, which enhance solubility, protect active compounds from degradation, and allow sustained and targeted release within the oral cavity. Incorporating Curcuma and Amla extracts into a **nanoparticle-infused gel** provides multiple benefits: easy application, prolonged contact with teeth and gums, enhanced antimicrobial activity, and improved patient compliance. Such formulations can efficiently penetrate dental biofilms, disrupt plaque formation, and promote healthier oral conditions without the adverse effects seen in conventional chemical agents. In conclusion, the combination of

Curcuma longa and Phyllanthus emblica in a nanoparticle- infused gel represents a safe, natural, and innovative strategy for plaque removal and overall dental care. By integrating the **traditional wisdom of herbal medicine** with **modern nanotechnology**, this approach holds significant promise for future dental therapeutics, offering an effective alternative for maintaining oral hygiene and preventing caries.

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