e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(4); 1408-1427

Review Article

The Therapeutic Role of Curcumin on Oral Disease Management: A Review

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Received: 01-01-2026 / Revised: 15-02-2026 / Accepted: 21-03-2026

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Conflict of interest: Nil

Abstract

Background: Curcumin, the principal bioactive compound of turmeric (Curcuma longa), has gained considerable attention due to its anti-inflammatory, antioxidant, antimicrobial, and anticancer properties. Its potential role in oral healthcare has been increasingly explored as an alternative or adjunct to conventional therapies, which are often associated with adverse effects and antimicrobial resistance.

Aim: The aim of this review was to systematically evaluate the therapeutic efficacy of curcumin in the management of various oral diseases and to identify optimal formulations and clinical outcomes.

Materials and Methods: This review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The research question was structured using the PICO framework. A comprehensive literature search was performed in PubMed, ScienceDirect, and Scopus for studies published between 2000 and 2026. Randomized controlled trials with Systematic Reviews and Meta-Analyses, evaluating curcumin formulations (gel, mouthwash, capsules, patches, or solutions) in oral diseases were included. A total of 21 studies met the inclusion criteria.

Results: Curcumin demonstrated significant therapeutic benefits across multiple oral conditions, including oral mucositis, periodontal diseases, recurrent aphthous stomatitis, oral submucous fibrosis, oral lichen planus, and oral potentially malignant disorders. Clinical outcomes included reduction in inflammation, pain, lesion size, and microbial load, along with improved healing. In several studies, curcumin showed comparable efficacy to conventional treatments such as chlorhexidine and corticosteroids. Advanced delivery systems, including nanoformulations, enhanced its clinical effectiveness.

Conclusion: Curcumin is a safe and effective multi-targeted agent with promising applications in oral disease management. However, limitations such as poor bioavailability, heterogeneity in study designs, and lack of standardized dosing protocols necessitate further large-scale randomized controlled trials to establish definitive clinical guidelines.

DOI: 10.25258/ijcpr.18.4.224

Introduction

Turmeric (Curcuma longa), widely known as "Indian saffron," is one of the most extensively utilized dietary spices and medicinal herbs in India and across Asia. It belongs to the Zingiberaceae (ginger) family, and its rhizomatous roots are rich in biologically active compounds, the most prominent of which is curcumin [1]. Curcumin is a naturally occurring polyphenolic diketone responsible for the characteristic yellow color of turmeric and is considered the principal pharmacologically active component. Over the past few decades, curcumin has gained considerable scientific interest due to its broad spectrum of biological activities, including antioxidant, anti-inflammatory, antimicrobial, antifibrotic, and anticancer properties [2]. Polyphenols such as curcumin play a pivotal role in maintaining cellular homeostasis by regulating oxidative stress,

modulating inflammatory signaling pathways, and influencing gene expression involved in cell proliferation, differentiation, and apoptosis [2,3].

In the context of oral health, these properties are particularly relevant because many oral diseases—such as periodontitis, oral mucosal lesions, and oral cancer—are strongly associated with chronic inflammation, oxidative stress, and dysregulated immune responses. Conventional therapeutic approaches, including antibiotics, corticosteroids, and antiseptic mouthwashes, although effective, are often associated with adverse effects such as mucosal irritation, microbial resistance, and long-term toxicity. These limitations highlight the growing need for safer, biocompatible, and cost-effective therapeutic alternatives [3,4]. Globally, nearly 80% of the population in developing countries relies on traditional herbal medicine for primary healthcare needs, underscoring the importance of plant-derived bioactive compounds in modern therapeutics [4-6]. Turmeric has been used for more than 4000 years in Ayurvedic and traditional medicine systems for the treatment of inflammatory disorders, wound healing, and infections. Chemically, turmeric contains approximately 3–5% curcuminoids, including curcumin, demethoxycurcumin, and bisdemethoxycurcumin, which act synergistically to produce therapeutic effects [5,7].

Role of Curcumin in Oral Health

Curcumin has demonstrated significant therapeutic potential across a wide spectrum of oral diseases, including:

- Recurrent aphthous stomatitis (RAS)
- Oral submucous fibrosis (OSMF)
- Oral leukoplakia and other potentially malignant disorders
- Oral candidiasis
- Gingivitis and periodontitis
- Oral mucositis

Its beneficial effects are mediated through multiple mechanisms such as suppression of inflammatory mediators, scavenging of reactive oxygen species, inhibition of microbial growth, and modulation of immune responses [6–11].

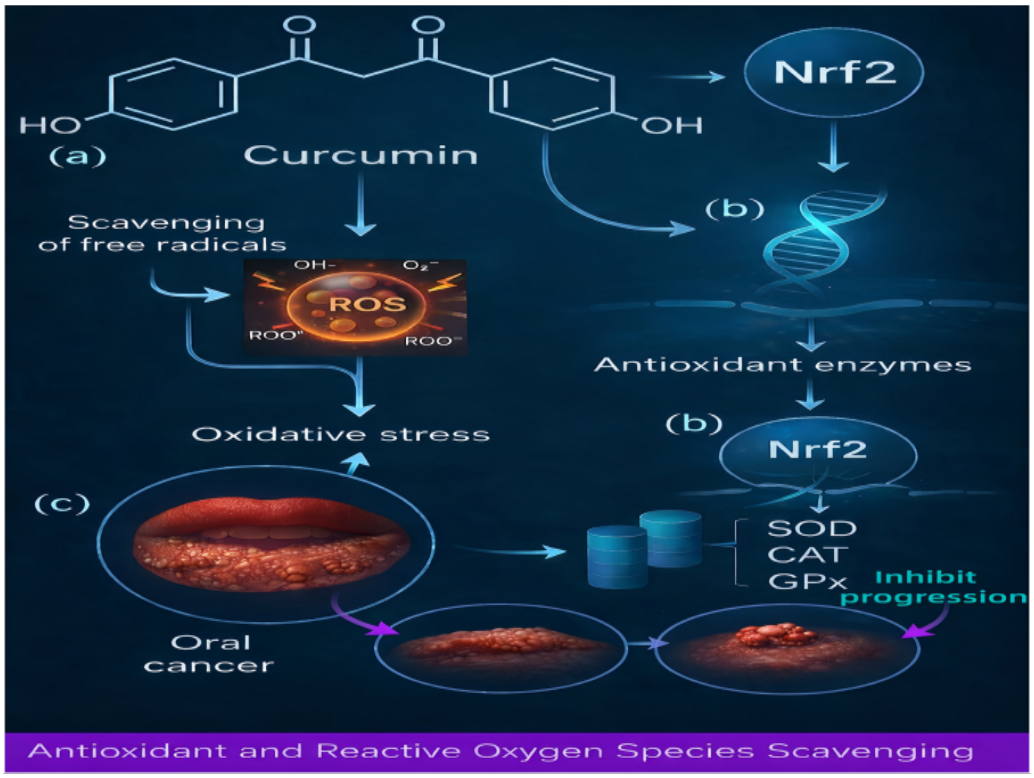


Figure 1: Mechanism of Action of Curcumin in Oral Diseases: [11]

Key Mechanisms of Curcumin in Oral Diseases:

1. Inhibition of NF-κB Signaling Pathway: Curcumin exerts a potent anti-inflammatory effect primarily through inhibition of the NF-κB signaling pathway, a central regulator of inflammatory gene expression. Under pathological conditions, NF-κB is activated via phosphorylation and degradation of its inhibitor IκB by IκB kinase (IKK). Activated NF-κB translocates to the nucleus and induces transcription of pro-inflammatory genes [12-14].

Curcumin inhibits this pathway at multiple levels:

- Prevents activation of IKK, thereby stabilizing IκB

- Inhibits nuclear translocation of NF-κB (p65 subunit)
- Suppresses NF-κB DNA-binding activity

As a result, downstream inflammatory mediators are significantly reduced, leading to attenuation of chronic inflammation in periodontal tissues and oral mucosa.

2. Downregulation of Pro-inflammatory Cytokines

Curcumin suppresses the production and release of key pro-inflammatory cytokines, including:

- Interleukin-1 beta (IL-1β)
- Interleukin-6 (IL-6)
- Tumor necrosis factor-alpha (TNF-α)

These cytokines play a critical role in the pathogenesis of oral inflammatory diseases such as periodontitis, oral mucositis, and oral submucous fibrosis. By downregulating these mediators, curcumin:

- Reduces tissue inflammation and edema
- Limits immune cell infiltration
- Prevents connective tissue degradation

This cytokine modulation contributes to both symptom relief and disease progression control.

3. Suppression of COX-2 and iNOS Expression

Curcumin inhibits the expression of key inflammatory enzymes:

- Cyclooxygenase-2 (COX-2)
- Inducible nitric oxide synthase (iNOS)

COX-2 is responsible for the synthesis of pro-inflammatory prostaglandins, while iNOS catalyzes the production of nitric oxide (NO), a mediator of oxidative stress and inflammation.

By suppressing these enzymes, curcumin:

- Decreases prostaglandin E2 (PGE2) levels
- Reduces nitric oxide-mediated tissue damage
- Limits oxidative injury in oral tissues

This mechanism is particularly relevant in conditions like gingivitis, periodontitis, and oral mucositis [13-19].

4. Activation of Antioxidant Pathways (Nrf2/HO-1 Axis)

One of the most critical cytoprotective mechanisms of curcumin involves activation of the Nrf2/HO-1 pathway, a master regulator of cellular antioxidant defense.

Mechanism of Action: Under normal conditions, nuclear factor erythroid 2–related factor 2 (Nrf2) is bound to its inhibitor Keap1 in the cytoplasm and is targeted for degradation. Curcumin disrupts this interaction, leading to:

- Stabilization and activation of Nrf2
- Translocation of Nrf2 into the nucleus
- Binding to antioxidant response elements (ARE) in DNA

This results in transcriptional activation of several antioxidant and cytoprotective genes, including:

- Heme oxygenase-1 (HO-1)
- Superoxide dismutase (SOD)
- Catalase
- Glutathione peroxidase (GPx)

Biological Effects:

- Neutralization of reactive oxygen species (ROS)
- Reduction of oxidative stress-induced cellular damage
- Protection of oral epithelial cells and fibroblasts
- Enhancement of tissue repair and wound healing

Clinical Relevance: Oxidative stress plays a crucial role in oral diseases such as:

- Periodontitis
- Oral mucositis
- Oral cancer

By activating the Nrf2/HO-1 pathway, curcumin not only prevents oxidative damage but also complements its anti-inflammatory action, creating a dual protective effect in oral tissues [20-28].

5. Induction of Apoptosis

Curcumin induces programmed cell death (apoptosis), particularly in dysplastic and malignant cells, through both intrinsic (mitochondrial) and extrinsic pathways.

Key mechanisms include:

- Activation of caspases (caspase-3, -8, -9)
- Upregulation of pro-apoptotic proteins (Bax)
- Downregulation of anti-apoptotic proteins (Bcl-2)
- Disruption of mitochondrial membrane potential

This selective cytotoxicity toward abnormal cells makes curcumin a promising adjunct in oral cancer therapy and prevention of malignant transformation in potentially malignant disorders [29-36].

6. Inhibition of Angiogenesis and Tumor Progression: Curcumin inhibits tumor growth and metastasis by suppressing angiogenesis—the formation of new blood vessels essential for tumor survival.

It achieves this by:

- Downregulating vascular endothelial growth factor (VEGF)

- Inhibiting matrix metalloproteinases (MMPs)
- Suppressing endothelial cell proliferation

Additionally, curcumin interferes with multiple oncogenic signaling pathways, including:

- Epidermal growth factor receptor (EGFR)
- MAPK signaling cascade
- PI3K/Akt pathway

These actions collectively:

- Limit tumor vascularization
- Prevent invasion and metastasis
- Enhance sensitivity to chemotherapy and radiotherapy

Curcumin acts as a multi-target therapeutic agent, simultaneously modulating inflammatory, oxidative, immunological, and oncogenic pathways.

Its ability to influence both upstream regulators (NF-κB, Nrf2) and downstream effectors (cytokines, enzymes, growth factors) makes it uniquely effective in managing a wide spectrum of oral diseases [37-45].

Table 1: Properties and signaling pathways of curcumin.

Category	Details
Anti-inflammatory	COX-1, COX-2, LOX, TNF-α, IFN-γ, iNOS and NF-κB inhibition [76]
	Down-regulates MCP-1 expression[77]
	Inhibits inflammatory cytokines production: IL-1β, IL-2, IL-5, IL-6, IL-8, IL-12, IL-18, MIP-1α [78]
Anti-inflammatory	Down-regulates mitogen-activated and Janus kinases [79]
Anti-neoplastic via cell-cycle arrest	Cyclin D1 and CDK4 inhibition and p53, pRb, p21 and p27 up-regulation [80,81]
	Induced retinoblastoma protein [81] and STAT3 [82] phosphorylation and down-regulates cyclin D1 and cyclin E expression [81,82]
Induction of apoptotic signals	Induced up-regulation of Fas, FasL and DR5 expression [83]
	Enhances procaspases 3, 8 and 9 and poly(ADP-ribose) polymerase cleavage [84]

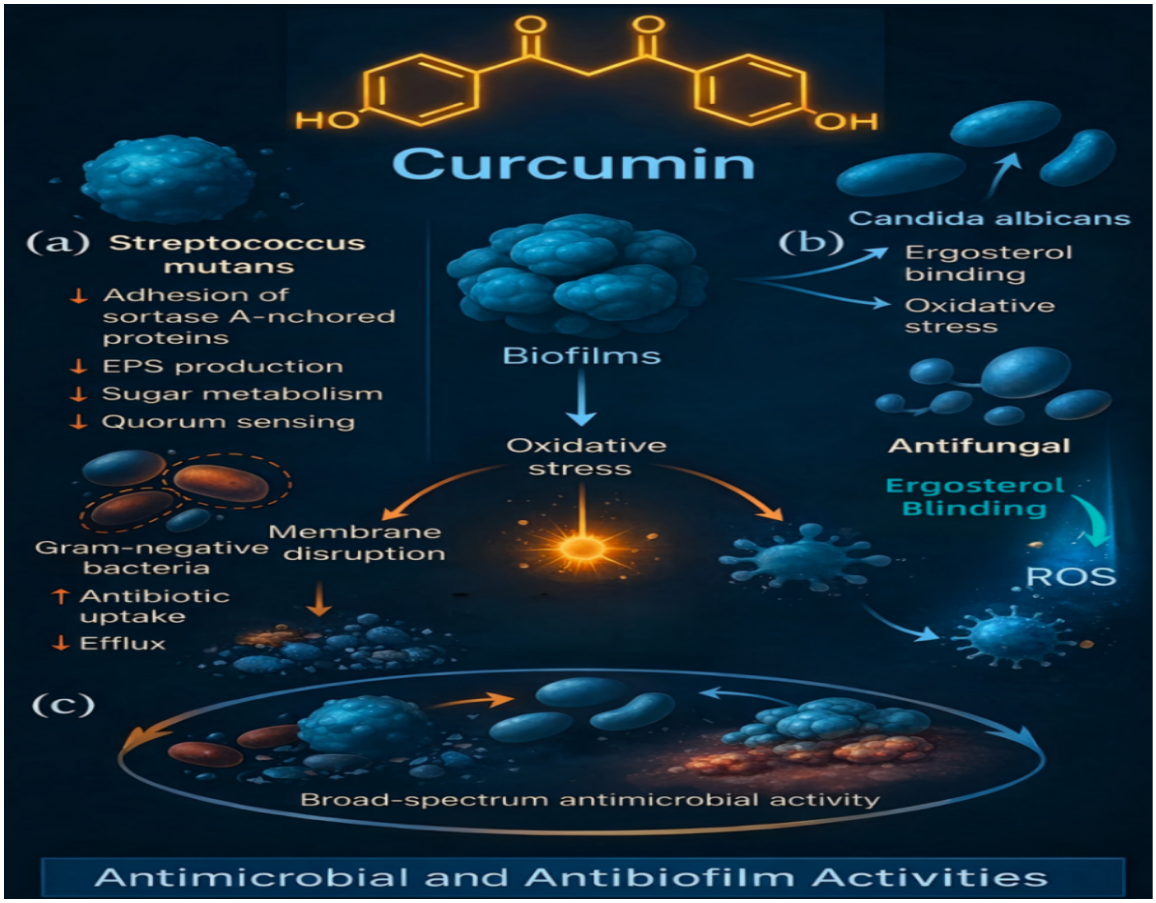


Figure 2: Antimicrobial and Antibioflim activities of Curcumin [37]

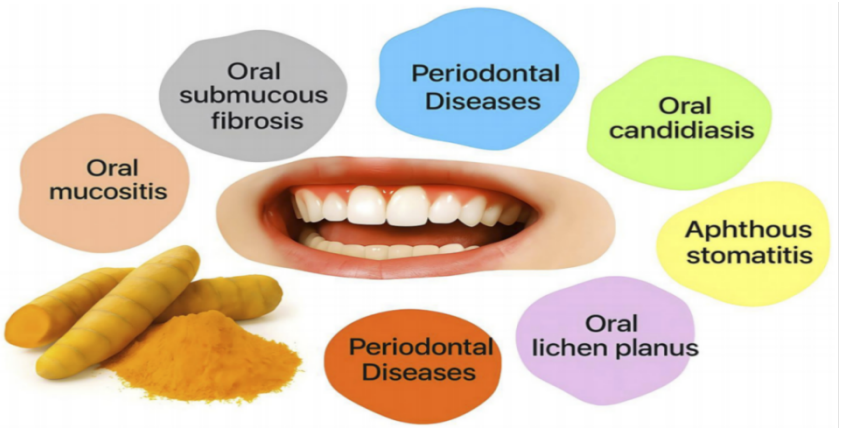


Figure 3: Clinical Applications of Curcumin in Dentistry: [47].

Table 2: Dental Applications of Curcumin and Clinical Outcomes [2-71]

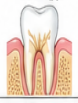
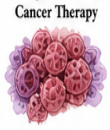
Application	Formulation	Clinical Effect	Reference
Dental pain	Topical turmeric paste	Reduces pain & inflammation	[2]
Gingivitis/Periodontitis	Turmeric + salt + mustard oil	Improves gingival health	[2]
Mouthwash	Curcumin solution	Comparable to chlorhexidine	[31]
Local drug delivery	2% turmeric gel	Reduces pocket depth & inflammation	[32]
Subgingival irrigant	1% curcumin	Reduces bleeding and redness	[33]

Table 3: Clinical Applications of Curcumin in Oral Diseases [2-71]

Clinical Application	Formulation / Mode of Use	Mechanism of Action	Key Clinical Outcomes	References
Oral Mucositis Management	Mouthwash, gel, nanomicelle formulations	Anti-inflammatory (↓ NF-κB, TNF-α), antioxidant (Nrf2 activation), mucosal healing	Reduced severity of mucositis, pain relief, faster epithelial healing	[10, 11, 24, 25, 30]
Periodontal Therapy (Gingivitis & Periodontitis)	Mouthwash, local drug delivery gel (2%), subgingival irrigant (1%)	Antimicrobial, anti-inflammatory, inhibition of cytokines (IL-1β, IL-6), plaque reduction	Decreased plaque index, gingival index, probing depth; improved attachment levels	[12, 13, 31, 32, 33]
Recurrent Aphthous Stomatitis (RAS)	Topical gel, orabase, nanocurcumin	Anti-inflammatory, analgesic, epithelial regeneration	Reduced ulcer size, pain reduction, faster healing time	[18, 21, 24]
Oral Submucous Fibrosis (OSMF)	Capsules, topical gel, combination with piperine or physiotherapy	Antifibrotic (↓ TGF-β), antioxidant, anti-inflammatory	Improved mouth opening, reduced burning sensation, slowed fibrosis progression	[11, 12, 14, 15, 19, 20]
Oral Leukoplakia & OPMDs	Oral capsules, systemic administration	Antioxidant, antiproliferative, apoptosis induction	Reduction in lesion size, decreased dysplasia risk	[13, 26, 35]
Oral Lichen Planus (OLP)	Topical gel, nano-curcumin	Immunomodulatory, anti-inflammatory (↓ cytokines), antioxidant	Symptom relief (burning, pain), lesion regression	[18, 20]
Adjunct in Oral Cancer Therapy	Oral/systemic curcumin, combination with radiotherapy/chemotherapy	Induces apoptosis, inhibits angiogenesis, suppresses COX-2 & EGFR pathways	Enhanced radiosensitivity, reduced tumor proliferation, improved treatment response	[34, 42, 60–64, 68–71]

Antimicrobial Applications	Mouthwash, gel, photodynamic therapy	Disruption of bacterial cell membranes, inhibition of biofilm formation	Reduced oral microbial load, plaque control	[16, 27, 28]
Antifungal Applications (Candidiasis)	Topical gel, mouthwash	Inhibits fungal growth, disrupts cell membrane integrity	Effective against Candida species, reduction in denture stomatitis	[16, 29]
Dental Pain & Inflammation	Topical turmeric paste	Anti-inflammatory, analgesic	Relief from dental pain and gingival inflammation	[2]
Drug Delivery Systems	Nanoparticles, liposomes, micelles, gels	Improved bioavailability, sustained release, enhanced tissue penetration	Increased therapeutic efficacy with reduced dosage requirements	[9, 36]

Table 1. Clinical applications of curcumin in oral health: mechanisms, formulations, clinical outcomes and evidence

Application Area	Key Mechanisms of Action	Common Formulations and Delivery Systems	Clinical Outcomes / Benefits	Representative Evidence	Reference No.
1. Oral Mucositis Management 	• Inhibits NF-κB signaling and pro-inflammatory cytokines (IL-1β, IL-6, TNF-α • Scavenges reactive oxygen species (ROS) • Promotes epithelial cell proliferation and wound healing • Reduces pain and ulcer severity	• Curcumin mouthwash (0.1–0.2%) • Curcumin gel (1–2%) • Curcumin lozenges • Nanocurcumin gels	• Significant reduction in mucositis severity scores (WHO scale) • Decreased pain and erythema • Accelerated healing and improved quality of life • Safe with minimal adverse effects	Randomized trials show curcumin mouthwash or gel reduces mucositis severity and pain, and improves oral intake in patients receiving chemo/ radiotherapy.	[28, 29, 30]
2. Periodontal Therapy 	• Suppresses NF-κB, IL-1β, TNF-α, IL-6 • Inhibits COX-2 and prostaglandin synthesis • Reduces oxidative stress (↑Nrf2/HO-1) • Antimicrobial against periodontal pathogens • Modulates host immune response and reduces tissue destruction	• Curcumin gel (2%) as local drug delivery • Curcumin mouthwash (10–20 mg/100 mL) • Subgingival irrigant (1% curcumin solution)	• Reduction in probing pocket depth (PPD) • Gain in clinical attachment level (CAL) • Decreased bleeding on probing (BOP) • Reduced gingival inflammation • Lower microbial load and biofilm	Clinical studies demonstrate that curcumin as adjunct to SRP improves periodontal parameters and reduces inflammatory markers.	[31, 32, 33]
3. Oral Potentially Malignant Disorders (OPMDs) 	• Anti-fibrotic: inhibits TGF-β, CTGF and collagen deposition • Antioxidant and anti-inflammatory actions • Modulates epithelial dysplasia and cell proliferation • Reduces oxidative DNA damage	• Curcumin gel (1–2%) • Curcumin mouthwash (0.1–0.2%) • Curcumin capsules/tablets • Curcumin patches	• Improvement in mouth opening (OSMF) • Reduction in burning sensation and pain • Partial regression of leukoplakia and lichen planus lesions • Slowing or reversal of fibrotic changes	Clinical and histological studies show improvement in symptoms and partial reversal of lesions in OSMF, leukoplakia and lichen planus.	[35, 42, 43, 44]
4. Adjunct in Oral Cancer Therapy 	• Induces apoptosis (caspase activation) • Causes cell cycle arrest at G2/M phase • Inhibits angiogenesis (↓VEGF) • Downregulates oncogenic pathways (EGFR, PI3K/Akt, MAPK) • Enhances radio- and chemo-sensitivity	• Curcumin capsules/tablets • Curcumin nanoformulations • Curcumin gel/mouthwash (adjunct) • Curcumin with piperine	• Inhibits tumor cell proliferation and invasion • Reduces tumor size in experimental models • Enhances effectiveness of radiotherapy and chemotherapy • Improves survival outcomes in preclinical studies	Multiple *in vitro* and *in vivo* studies show curcumin inhibits OSCC growth, induces apoptosis and enhances radio/ chemo-sensitivity.	[34, 60–64, 68–71]
5. Antimicrobial and Antifungal Applications 	• Disrupts microbial cell membrane integrity • Inhibits adhesion and biofilm formation • Interferes with microbial enzyme activity • Exhibits broad-spectrum antibacterial and antifungal activity	• Curcumin mouthwash (0.1–0.2%) • Curcumin gel • Curcumin nanoparticles • Photodynamic therapy with curcumin	• Effective against *S. mutans*, *P. gingivalis*, *C. albicans* and other oral pathogens • Reduces plaque and biofilm formation • Comparable efficacy to chlorhexidine with fewer side effects • Useful in denture stomatitis and candidiasis	Clinical and *in vitro* studies report significant reduction in microbial load and biofilm; curcumin comparable to chlorhexidine in plaque control.	[6, 7, 31, 45–49]

Abbreviations: NF-κB: Nuclear factor kappa B; IL: Interleukin; TNF-α: Tumor necrosis factor-alpha; COX-2: Cyclooxygenase-2; Nrf2; Nuclear factor erythroid 2–related factor 2; HO-1: Heme oxygenase-1; PPD: Probing pocket depth; CAL: Clinical attachment level; BOP: Bleeding on probing; TGF-β: Transforming growth factor-beta; CTGF: Connective tissue growth factor; VEGF: Vascular endothelial growth factor; O CC: Oral squamous cell carcinoma.

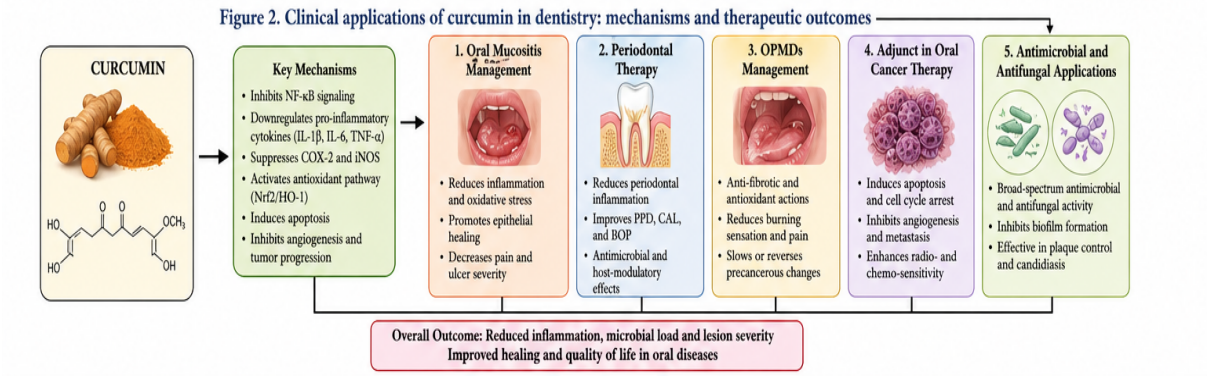


Figure 4:

Tables-1-3, summarizes the diverse clinical applications of curcumin in oral health, highlighting its multi-targeted therapeutic potential. Across various oral conditions—including oral mucositis, periodontal diseases, recurrent aphthous stomatitis, and oral submucous fibrosis, and oral potentially malignant disorders— curcumin demonstrates consistent clinical benefits.

These effects are primarily mediated through its anti-inflammatory, antioxidant, antimicrobial, and antifibrotic mechanisms. The tables further illustrates that multiple formulations (e.g., mouthwash, gels, local drug delivery systems, and nanocarriers) enhance its clinical applicability. Notably, curcumin-based therapies show comparable efficacy to conventional agents such as chlorhexidine, with the added advantage of fewer adverse effects. In oncological settings, curcumin also exhibits adjunctive benefits by enhancing radiosensitivity and inhibiting tumor progression.

Figure-1 &2: (Mechanism of Action of Curcumin) provides a schematic overview of the molecular pathways through which curcumin exerts its therapeutic effects. It demonstrates that curcumin acts on key signaling cascades, particularly by inhibiting the NF-κB pathway, downregulating pro-inflammatory cytokines (IL-1β, IL-6, TNF-α), suppressing COX-2 and iNOS expression, and activating antioxidant pathways such as Nrf2/HO-1. Additionally, the figure highlights curcumin's role in inducing apoptosis and inhibiting angiogenesis, thereby supporting its anticancer potential.

Table-3 (Clinical Applications of Curcumin in Dentistry) visually integrates these mechanistic insights with clinical outcomes. It illustrates how the molecular actions of curcumin translate into therapeutic benefits across different oral diseases. The figure emphasizes a central concept: curcumin's ability to reduce inflammation, microbial load, and lesion severity ultimately leads to improved healing and overall oral health outcomes. The flowchart also underscores the versatility of curcumin as both a primary and adjunctive therapeutic agent in dental practice.

Curcumin represents a promising adjunct in oral healthcare owing to its multifaceted pharmacological actions, including anti-inflammatory, antioxidant, antimicrobial, and anticancer effects. Its therapeutic versatility, combined with emerging advanced delivery systems, supports its potential integration into contemporary dental practice.

Nevertheless, current evidence is limited by heterogeneity in study design, small sample sizes, and a predominance of preclinical data. In addition, issues related to poor bioavailability, lack of standardized formulations, and absence of uniform dosing protocols hinder its widespread clinical translation. Therefore, robust, large-scale randomized controlled trials with standardized methodologies are warranted to establish definitive clinical efficacy and optimize its therapeutic application.

Previous studies have not clearly identified which oral diseases respond most effectively to curcumin therapy. In contrast, the present review analyzes 21 studies across six oral mucosal conditions, highlighting statistically significant outcomes and optimal curcumin formulations.

Despite its therapeutic potential, curcumin is limited by poor bioavailability due to low aqueous solubility, restricted systemic distribution, and inadequate intestinal absorption [9, 72-90]. Nevertheless, the findings of this review provide clinically relevant insights to guide the selection of curcumin-based therapies in the management of oral diseases.

Materials and Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The research question was formulated using the PICO framework, where the population included patients with oral diseases, the intervention involved curcumin-based therapies, the comparison group received conventional or placebo treatments, and the outcomes assessed were clinical effectiveness and therapeutic benefits.

Data Sources and Search Strategy: A comprehensive literature search was performed using electronic databases, including PubMed, ScienceDirect, and Scopus.

The search strategy incorporated combinations of keywords such as: "oral disease," "oral mucosal lesions," "curcumin," "turmeric," and "therapeutic effects," using Boolean operators (AND/OR) to identify relevant studies.

Inclusion and Exclusion Criteria:

Studies were included if they met the following criteria: (1) published in international peer-reviewed journals between 2000 and 2026; (2) available in full text and written in English; (3) designed as randomized controlled trials (RCTs); and (4) evaluated curcumin in various formulations (e.g., gels, mouthwashes, capsules, patches, or solutions) for the management of oral diseases.

Studies were excluded if they were duplicates, irrelevant to the study objective, or did not follow an RCT design. Limiting the search to the last 25 years ensured the inclusion of contemporary

evidence aligned with recent advances in drug delivery systems and clinical practice.

PRISMA Flow Diagram:

Identification: Records identified through database searching: n = 100

- PubMed: 42
- ScienceDirect: 31
- Scopus: 30

Additional records identified through other sources (manual/reference screening): **n = 7**

Total records: n = 100

Study Selection and Characteristics

Table 4: Summary of Included Studies (n = 21)

Category	Number of Studies	Study Design	Intervention (Curcumin Form)	Comparison	Key Outcomes
Oral Mucositis	4	RCT	Mouthwash, gel, nanomicelle	Placebo / standard care	↓ Severity, ↓ pain, faster healing
Periodontal Diseases	5	RCT	Mouthwash, gel, irrigant	Chlorhexidine / SRP	↓ plaque, ↓ GI, ↓ PPD
Recurrent Aphthous Stomatitis	3	RCT	Topical gel, orabase	Placebo / steroids	↓ ulcer size, ↓ pain
Oral Submucous Fibrosis (OSMF)	5	RCT	Capsules, gel, combination therapy	Steroids / lycopene	↑ mouth opening, ↓ burning sensation
Oral Lichen Planus	2	RCT	Nano-curcumin, topical gel	Steroids	↓ inflammation, symptom relief
Leukoplakia / OPMDs	2	RCT	Oral capsules	Placebo	↓ lesion size, ↓ dysplasia progression

Discussion

Curcumin, the principal bioactive compound of Curcuma longa, has emerged as a promising therapeutic agent in oral medicine due to its pleiotropic biological activities.

The present review synthesizes evidence from 21 randomized controlled trials (RCTs) and supporting mechanistic studies, review articles, highlighting its clinical efficacy across multiple oral diseases.

Overall Therapeutic Potential of Curcumin: The findings of this review demonstrate that curcumin exerts multi-targeted effects, including anti-inflammatory, antioxidant, antimicrobial, antifibrotic, and anticancer actions. These properties are primarily mediated through modulation of key molecular pathways such as NF-κB, COX-2, and pro-inflammatory cytokines [2,6,42,60- 71].

Clinical outcomes across studies consistently indicate symptom reduction, improved healing, and decreased disease progression, supporting curcumin's role as both a primary and adjunctive therapeutic agent [8,10].

Disease-wise Discussion:

Oral Mucositis: Oral mucositis is a common complication of chemotherapy and radiotherapy. Curcumin has shown significant efficacy in reducing mucosal inflammation and promoting healing.

- Studies reported reduction in mucositis severity, pain, and ulceration [10,24,25, 76-81]
- Mechanism: inhibition of NF-κB and oxidative stress pathways
- Nanocurcumin formulations further enhanced bioavailability and therapeutic outcomes [24, 82-86]

Table 5: Curcumin in Oral Mucositis [10-25]

Study	Intervention	Key Findings	Reference
Rao et al.	Curcumin mouthwash	↓ mucositis severity	[10]
Delavarian et al.	Nanomicelle curcumin	Preventive effect	[24]
Ramezani et al.	Curcumin therapy	↓ radiation-induced mucositis	[25]

Periodontal Diseases: Curcumin has demonstrated comparable efficacy to chlorhexidine in managing gingivitis and periodontitis.

- Significant reduction in plaque index, gingival index, and probing depth [81–93]
- Exhibits antimicrobial activity against periodontal pathogens
- Enhances healing when used as an adjunct to scaling and root planing (SRP)

Table 6: Curcumin in Periodontal Therapy

Study	Formulation	Outcome	Reference
Waghmare et al.	Mouthwash	Comparable to chlorhexidine	[31]
Behal et al.	2% gel	↓ PPD, ↑ attachment	[32]
Suhag et al.	Irrigant	↓ BOP, ↓ inflammation	[33]

Recurrent Aphthous Stomatitis (RAS)

Curcumin has shown promising results in the management of RAS due to its anti-inflammatory and analgesic properties.

- Reduced ulcer size, pain, and healing time [18,21, 94-96]
- Comparable efficacy to topical corticosteroids

Oral Submucous Fibrosis (OSMF)

OSMF is a chronic, progressive, fibrotic disorder with malignant potential. Curcumin plays a significant antifibrotic role.

- Improvement in mouth opening and reduction in burning sensation [11–15,19, 97-100]
- Mechanism: inhibition of TGF-β and collagen synthesis
- Combination therapies (e.g., curcumin + piperine) enhanced outcomes.

Table 7: Curcumin in OSMF

Study	Intervention	Outcome	Reference
Yadav et al.	Curcumin vs steroid	Comparable improvement	[11]
Pipalia et al.	Curcumin + piperine	Enhanced bioavailability	[12]
Bhowate et al.	Curcumin gel	↓ fibrosis	[19]

Oral Potentially Malignant Disorders (OPMDs)

Curcumin exhibits chemopreventive effects in leukoplakia and related lesions.

- Reduction in lesion size and dysplasia progression [13,35]
- Antioxidant and antiproliferative properties play a major role

Oral Lichen Planus (OLP)

Curcumin's immunomodulatory properties are beneficial in managing OLP.

- Significant reduction in burning sensation and lesion severity [18,20]
- Nano-curcumin formulations improved therapeutic outcomes

Oral Cancer and Anticancer Mechanisms

Curcumin exhibits strong anticancer activity through multiple mechanisms:

- Induces apoptosis and cell cycle arrest (G2/M phase) [34]
- Inhibits angiogenesis and metastasis [60–64]
- Enhances radiosensitivity in oral cancer cells [68–71]

Preclinical models showed:

- 91% reduction in tumor incidence in chemically induced carcinogenesis [61, 98]

Mechanistic Insights

Curcumin's therapeutic effects are mediated through:

- Inhibition of NF-κB pathway → ↓ cytokines (IL-1β, TNF-α)
- Suppression of COX-2 and iNOS
- Activation of antioxidant pathways (Nrf2/HO-1)
- Modulation of immune response and macrophage polarization

These mechanisms collectively contribute to reduced inflammation, enhanced healing, and tumor suppression [42,60, 87-91].

Role of Drug Delivery Systems

One of the major limitations of curcumin is its poor bioavailability [9]. Recent advances include:

- Nanoparticles and liposomes
- Micelles and hydrogels
- Local drug delivery systems

These innovations significantly improve absorption, stability, and clinical efficacy [36, 67, 77-80].

Strength of Evidence

- Majority of included studies are RCTs, enhancing reliability
- Consistent findings across multiple oral conditions
- Supported by strong mechanistic and preclinical evidence

Limitations of Current Evidence

Despite promising results:

- Small sample sizes in many RCTs
- Heterogeneity in formulations and dosages
- Limited long-term follow-up

- Predominance of adjunctive rather than standalone therapy

Clinical Implications

Curcumin can be effectively used as:

- Adjunct to conventional periodontal therapy
- Alternative to corticosteroids in mucosal lesions
- Supportive therapy in oral cancer management
- Preventive agent in OPMDs

Future Directions

Future research should focus on:

- Standardized dosing protocols
- Large multicentric RCTs
- Advanced nanoformulations
- Long-term safety and efficacy studies

Table 7: Summary of the selected articles. [64- 95]

Authors	Type of the Study	Age and Numbers of Participants	Aim of the Study	Materials and Clinical Data	Results and Percentages
Cindy Grace Pérez-Pacheco et al., 2021 [76]	Double-blind split-mouth randomized clinical trial.	Twenty male and female participants in good health, aged 30 years or older.	Examination of a single local application of nanoparticles loaded with curcumin as a complementary treatment for nonsurgical periodontal therapy to SRP.	SRP + empty nanoparticles or SRP + PLGA (Poly lactide-co-glicolide)/ PLA (polu lactide) nanoparticles loaded with 50 µg of curcumin (N-Curcumin) were administered to twenty healthy patients with periodontitis. Monitoring was placed at baseline, 30, 90, and 180 days for PPD, CAL, and BOP.	In the periodontally infected areas, a single local dosage of nanoencapsulated curcumin did not enhance the clinical outcome.
Hayder Thabit Farhood et al., 2020 [77]	Clinical random split-mouth interventional study.	Twenty Iraqi patients aged 21-45 years, comprising 9 males and 11 females.	The purpose of the study was to evaluate the efficacy of subgingival SRP with a curcumin oral gel as an adjuvant treatment and to compare the results with SRP alone.	Patients with bilateral 5 to 7 mm pockets exclusively in the upper jaw and periodontitis (stage II/III, grade AC) were chosen at random. Using the split-mouth approach, one side was designated as the control group and received SRP alone; the other side was designated as the test group and received two applications of the curcumin oral gel in addition to SRP spaced one week apart.	According to the study's findings, the curcumin oral gel significantly improved all clinical periodontal parameters when compared to the baseline, with the test group experiencing a more noticeable improvement in PPD, CAL, PI, and GI.
Mansour Al-Askar et al., 2022 [78]	Clinical study.	Two groups of seventy-six periodontitis patients were randomly assigned. The test and control groups' mean ages were 57.2 ± 5.2 and	To evaluate the comparative analgesic effectiveness of mefenamic acid (MA) and curcumin administered orally following surgical periodontal	Patients were administered 200 mg curcumin capsules in the test group and 500 mg of MA in the control group.	Curcumin was not as effective as MA for treating pain and discomfort following SPT.

		58.4 ± 7.3 years, respectively.	treatment (SPT).		
Reham Abdel-Fatah et al., 2023 [79]	Clinical study.	In the study, eighteen healthy volunteers and thirty-six periodontitis patients took part. The participants ranged in age from thirty to fifty-five years old, representing both genders.	To assess the impact of SRP in conjunction with a curcumin gel on salivary procalcitonin during treating periodontitis.	Three groups of participants were created: group I was made up of people with healthy gums; group II had a scaling and root planning treatment; and group III received weekly applications of a curcumin gel for four weeks following SRP treatment.	Compared to SRP, the application of the curcumin gel was observed to have a substantial impact on all clinical indicators.
Sanjeela Rakshith Guru et al., 2020 [80]	Clinical trial.	Forty-five people with long-term periodontitis, aged 25 to 50 years.	To compare the effectiveness of a 1% chlorhexidine gel and 2% curcumin with nanocarriers as a local drug delivery for the treatment of periodontal pockets.	Patients who had at least two teeth with pockets that were 5-7 mm deep were chosen. Microbiological analysis and clinical parameter assessment were performed at baseline, day 21, and day 45.	The findings demonstrated that all clinical parameters improved when the two local drug delivery (LDD) medications were administered in addition to SRP for chronic periodontitis.

Authors	**Type of the Study**	**Age and Numbers of Participants**	**Aim of the Study**	**Materials and Clinical Data**	**Results and Percentages**
Mallapragada Siddharth et al., 2020 [81]	Randomized controlled trial.	Twenty-five people in the age category of ≥30 years who were in general good health.	To evaluate the benefits of adding a 0.2% chlorhexidine gel and a 2% curcumin gel subgingivally as an adjuvant to scaling and root planing (SRP).	Subgingival administration of 0.2% chlorhexidine gel in the control sites and 2% curcumin gel in the experimental sites was carried out following a full-mouth SRP. Subgingival plaque samples were taken once more at one and three months, and measurements of site-specific periodontal parameters were made.	Periodontal measurements improved significantly according to statistical analysis in the experimental group (2% curcumin gel).
Sarah Adnan Alsalim et al., 2024 [82]	Clinical study.	Thirty-one head and neck cancer (HNC) patients over 16 years of	Comparison of the effectiveness of a curcumin oral gel versus the magic solution	Thirty-one HNC patients were divided into those treated with the curcumin oral gel	During the radiation treatments, the patients who took the oral

		age.	(mouthwash containing dexamethasone) for the treatment of radiation-induced oral mucositis (RIOM).	and those treated with the magic solution. Salivary epidermal growth factor (EGF) was quantified and RIOM was assessed using the WHO scale and visual analog scale (VAS).	curcumin gel had increased salivary EGF levels and less severe RIOM.
Swikant Shah et al., 2020 [83]	Randomized controlled trial.	Seventy-four patients.	Analysis of the effects on RIOM in 74 patients with head and neck cancer who were set to receive an RT of 0.15% benzydamine mouthwash and 0.1% freshly produced curcumin utilizing nanoparticles.	Every week for six weeks, RIOM was evaluated once a week using the WHO criteria. Two types of analyses, namely modified intention to treat (MIT) and per protocol (PP), were conducted to test the null hypothesis that there is comparable effectiveness between the prevention and severity of RIOM.	While mouthwashes were not able to stop RIOM from happening altogether or lessen its severity, using a mouthwash containing 0.1% curcumin was able to greatly postpone the onset of RIOM.
Lindsay Boven MD et al., 2018 [64]	Clinical trial	Ten healthy patients, 2 female and 8 male, between the ages of 30 and 68 years.	Validation of the effectiveness of curcumin gum by measuring its effects and evaluating its release and transmucosal absorption.	The residual curcumin chewed gum, serum, and saliva were measured by comparing the two chewing protocols, the initial and the revised chewing. Using a multiplex analysis, the levels of 15 proinflammatory cytokines in serum were examined.	It seems that improving mucosal contact is essential for enhancing curcumin absorption and release.

Authors	**Type of the Study**	**Age and Numbers of Participants**	**Aim of the Study**	**Materials and Clinical Data**	**Results and Percentages**
Rita de Cássia Dias Viana Andrade et al., 2022 [84]	Comparative randomized trial study.	Thirty patients (over 18 years old).	Assessment of the impact of curcumin and blue LED-mediated antimicrobial photodynamic therapy (aPDT) and photobiomodulation (PBM) as an adjuvant treatment for oral mucositis	Thirty patients (above the age of eighteen years) undergoing radiation and/or chemotherapy for stable oral mucosal lesions. Patients were assigned to three groups: aPDT group, PBM group,	Mucositis and pain degree scores decreased in both the PBM and aPDT groups; however, the aPDT group demonstrated early clinical improvement in contrast to the PBM group and the control group.

			undergoing chemotherapy or radiation therapy.	and control group.	Regarding antibacterial efficacy, aPDT showed a greater reduction in Candida yeasts throughout the parameters that were studied.
Basudev Mahato et al., 2019 [85]	Clinical study.	Forty patients. Mean age of 34.75 years. Age range of 18–62 years.	Evaluation of the efficacy of curcumin, lycopene, and piperine as a combination in the management of OSMF.	Biocumin (Biochem India) tablet with Curcumin (500 mg), piperine (5 mg), and lycopene (25 mg) twice a day for 3 months. Clinical evaluations of the respondents were conducted every 15 days until a 3-month follow-up. Mouth opening (MO), mucosal flexibility (MF), tongue protrusion (TP), and burning sensation score on the VAS were the parameters.	A considerable enhancement in the VAS score for burning sensation and a rise in MO ($p < 0.001$), MF, and TP were noted. Reepithelialization was also seen in the post-treatment histological assessment. Col1A1-based immunohistochemical investigations revealed a reduction in collagen deposition.
Tej Prakash Soni et al., 2021 [86]	Randomized double-blind placebo-controlled trial.	Sixty patients with oral cancer aged between 18 and 70 years.	Examination the impact of a turmeric formulation on patients undergoing chemotherapy and radiation therapy for oral cancer in terms of oral mucositis.	For six weeks, chemoradiotherapy was administered in addition to the daily administration of a bio-enhanced turmeric formulation (BTF) capsules (low dose [1 g/day] or high dose [1.5 g/day]) or placebo.	Patients with oral cancer who experience severe oral mucositis, dysphagia, oral pain, and dermatitis due to chemotherapy and radiation therapy can greatly benefit from BTF (BCM-95®).
Mellekatte C Neetha et al., 2020 [87]	Double-blind, randomized preliminary study.	Sixty subjects with oral potentially malignant disorders (OPMDs)	Evaluation of the combined effects of curcumin and a green tea extract in patients with OPMDs and determination of these chemopreventive drugs' mode of action by evaluating the relevant biomarkers.	For three months, the patients were randomized to receive either a green tea extract (800 mg/day applied topically and systemically) or curcumin (950 mg/day applied topically and systemically) or a combination therapy. There were 20 patients in each group. Biomarkers (p53,	When comparing the combination group to the curcumin and green tea extract groups, the combination group had a greater clinical response rate. When comparing the combination group's p53, Ki67, and cyclin D1 expression after three months to the baseline, there was a statistically significant downregulation.

				cyclin D1, and Ki67) were assessed in biopsies taken at baseline and after 12 weeks.	

Authors	Type of the Study	Age and Numbers of Participants	Aim of the Study	Materials and Clinical Data	Results and Percentages
Saroj K Basak et al., 2020 [88]	Double-blind, randomized, placebo-controlled, phase 1 clinical trial.	Thirteen normal subjects and twelve patients with oral cancer.	To assess that APG-157 could serve as a therapeutic drug in combination with immunotherapy.	Two doses, either 100 mg or 200 mg, were administered every hour for a total of 3 h. Blood and saliva samples were collected before treatment and at 1 h, 2 h, 3 h, and 24 h post-treatment.	The results indicated that circulating concentrations of curcumin and its analogs peaked at 3 h, accompanied by decreased concentrations of interleukin 1ß (Il-1ß), interleukin-6 (Il-6), and interleukin-8 (Il-8) in the salivary supernatant fluid of the cancer patients.
Deshmukh and Bagewadi, 2014 [89]	Randomized clinical trial.	Sixty patients of either sex.	To assess and compare the efficacy of a curcumin gel with triamcinolone acetonide gel in the treatment of minor RAS.	The patients were randomly assigned to two groups: the curcumin gel group (Group I) and the triamcinolone acetonide gel group (Group II). Patients applied the gel three times a day to each ulcer. The evaluation of effectiveness was based on the time needed for pain, size, and number of ulcers to regress.	Both groups showed a significant improvement in the size, pain, number, and duration of the ulcers within 7 days. No significant difference between the two groups in the treatment of recurrent aphthous stomatitis (RAS) were found.
Adhikari et al., 2022 [90]	Randomized, double-blind, parallel design, clinical trial.	Thirty-four patients.	To determine the efficacy of curcumin in combination with intralesional dexamethasone with hyaluronidase in the treatment of OSMF.	For six weeks, the patients were first treated with intralesional dexamethasone and hyaluronidase. Following this, Group A received curcumin (2	Both groups demonstrated significant improvements in MO, cheek flexibility, TP, and oral mucosa burning sensation. In Group A, the

				gm/day), while Group B received a placebo. At baseline and during the follow-up visits at 6, 8, and 12 weeks, measurements of interincisal mouth openness, TP, cheek flexibility, and VAS grading for burning sensation of the oral mucosa were taken.	mean differences in MO at 6, 8, and 12 weeks were 8.82 mm, 8.71 mm, and 8.06 mm, compared to Group B's mean differences of 5.53 mm, 5.35 mm, and 4.94 mm, respectively. Similar trends were observed in cheek flexibility and TP. Both groups achieved 100% improvement in burning sensation at all follow-up intervals.
Kia et al., 2020 [91]	Randomized controlled trial.	Sixty patients.	To evaluate the therapeutic effect of oral nano-curcumin as an alternative treatment for oral lichen planus (OLP) compared to prednisolone.	Patients were divided into two groups receiving either 80 mg nano-curcumin or 10 mg prednisolone treatments for 1 month. Pain severity and burning sensation were analyzed using the VAS scale, while lesion size was assessed using the Thongprasom scale.	Both the nano-curcumin and prednisolone groups showed a decrease in pain, burning sensation, and OLP lesions, with no statistically significant difference between the two groups.

Table 8: Summary of clinical trials evaluating curcumin formulations in various oral diseases

Disease	Study type	Delivery method	Dose/formulation	Age (Years)	Key outcomes	References
Periodontitis	RCT (n = 60)	Gel (2% curcumin)	Twice daily for 14 days	25–55	↓ Gingival Index, Probing Depth vs. SRP alone	Anuradha BR et al. J Indian Soc Periodontol. 2015; 19(3):302. (Anuradha et al., 2015)
Oral Mucositis (Radiotherapy)	RCT (n = 40)	Mouthwash (0.1%)	3x/day during RT	30–65	↓ Mucositis grade, ↓ Pain scores, ↑ Oral intake	Chakraborty, S et al. Br J Radiol. 2015; Apr; 88(1048):20140795. (Chakraborty et al., 2015)
Recurrent Aphthous	RCT (n =	Gel (5%)	Topical application 3x/day	18–45	↓ Healing time, ↓ Pain	Chainani-Wu N et al. J Altern

Ulcer	50)				comparable to triamcinolone gel	Complement Med. 2007; 13 (1): 123–9. (Chainani-Wu et al., 2007)
Oral Lichen Planus	RCT (n = 40)	Capsules (500 mg)	Twice daily for 3 months	35–60	↓ Burning sensation, ↓ Lesion size, comparable to steroids	Singh AK et al. J Maxillofac Surg. 2023 January-Apr; 14(1): 9–15. (Singh et al., 2023)
Oral Submucous Fibrosis	RCT (n = 100)	Tablets + Topical	600 mg/day + gel	20–50	↑ Mouth opening, ↓ Fibrosis stage	Rai, Arpita et al. J Stomatol Oral Maxillofac Surg. 2023 June; 124(3): 101423. (Rai et al., 2023)
Oral Cancer (APG-157 trial)	Phase I	Lozenge (APG-157)	100 mg/day	40–70	↓ IL-1β, IL-6, IL-8 in saliva; altered microbiome	Basak SK et al. Cancer. 2020; 126(Suppl 10):2056–69. (Basak et al., 2020)

Abbreviations: GI, gingival index; PI, plaque index; PPD, probing pocket depth; CAL, clinical attachment level; OM, oral mucositis; VAS, visual analog scale. All studies listed were indexed in PubMed and published in peer-reviewed journals.

Table 9: Emerging strategies combining curcumin with other agents for synergistic effects in oral health applications.

Formulation type	Carrier material/system	Route/application	Target disease/use	Key advantages	References
Mouthwash/rinse	Hydroalcoholic solution, nanomicelles	Rinse 2–3x daily	Gingivitis, Mucositis	Easy access to the entire oral cavity, rapid onset, and nanomicelles bioavailability	Abdel-Fatah, Reham et al. BMC oral health vol. 2023
Topical gel	Carbopol gel, Orabase, Chitosan gel	Direct lesion application	RAS, OLP, Post-SRP Healing	Sustained contact, lesion specificity, patient comfort	Idrees M. J Pers Med. 2023
Mucoadhesive film	Hydroxypropyl methylcellulose, Chitosan	Buccal mucosa, ulcer sites	OLP, Aphthous Ulcer	Prolonged mucosal adhesion, slow drug release, and minimal dosing frequency	Bapat RA et al. Environ Res. 2023
Lozenges/troches	APG-157 lozenges (proprietary nanocurcumin)	Oral cavity absorption	Oral Cancer, OSF	Enhances salivary and tissue absorption, modulates tumor microenvironment	Inchingolo F, et al. Antioxidants (Basel). 2024
Nanoparticles	Solid Lipid NP, Polymeric NP (PLGA), Nanoemulsions	Oral rinse or topical gel	Periodontitis, Biofilm infections	Cellular uptake, stability, and better plaque penetration	Bapat RA et al. Environ Res. 2023
Liposomal form	Phosphatidylcholine liposomes	Oral rinse	Oral Cancer, Mucositis	Lipid vesicle fusion with the mucosa improved tissue penetration	Dipalma G, et al. Antioxidants (Basel). 2024

Chewing gum	Gum base with emulsified curcumin	Buccal absorption during chewing	Oral inflammation, Caries prevention	Constant mucosal release, patient adherence	Inchingolo F et al. Antioxidants (Basel). 2024
Toothpaste	Herbal paste with curcumin	Twice daily brushing	Gingivitis, Caries	Daily exposure, antimicrobial and anti-inflammatory effects	Paradowska-Stolarz, Anna et al. Int J Mol Sci. 2021

Combination therapies hold potential for enhancing efficacy while minimizing side effects.

Table 10: Comparison of curcumin delivery systems designed for oral disease management.

Mechanism	Target pathway/molecule	Disease relevance	Evidence type	References
Anti-inflammatory	NF-κB, IL-1β, IL-6, TNF-α	Periodontitis, Mucositis, OLP	*In vitro*, Clinical	Inchingolo F et al. Biochem Pharmacol. 2024
Antioxidant	Nrf2, HO-1, SOD	OSF, Gingivitis, Cancer	*In vitro*, Animal	Sivani BM et al. Metabolites. 2022
Pro-apoptotic	Bax↑, Bcl-2↓, Caspase-3↑	OSCC, Leukoplakia	Cell line, Animal	Djaldetti M. Oncol Res. 2024
Anti-angiogenic	VEGF↓, HIF-1α↓	Oral Cancer, OSF	Animal, Xenograft	Sudhesh Dev S et al. Front Pharmacol. 2021
Anti-microbial	Biofilm Disruption, S. mutans	Gingivitis, Caries	*In vitro*	McCubrey JA et al. Aging (Albany NY). 2017
EMT inhibition	Snail↓, Twist↓, E-cadherin↑	OSCC (anti-metastatic)	Cell line	Hao M et al. Front Pharmacol. 2025
Immunomodulation	↑CD8+ T cells, ↓T-regs	Oral Cancer (immune checkpoint synergy)	Animal, Phase I	Antonangeli F et al. Front Immunol. 2020
Inhibits pro-inflammatory gene transcription	NF-κB	Periodontitis, Gingivitis	*In vitro*	Aggarwal BB et al. Adv Exp Med Biol. 2007
Blocks new vessel formation, impairs tumor supply	VEGF	Cancer Angiogenesis	*In vitro*, Cell line	Gupta SC et al. Cancer Metastasis Rev. 2018

The table highlights formulation types, carrier systems, advantages, and specific use cases supported by preclinical or clinical evidence. Data derived from PubMed-indexed trials and reviews published in highimpact journals.

Overall, the evidence supports curcumin as a safe, effective, and multifunctional therapeutic agent in oral healthcare. While its clinical application is promising, further high-quality research is essential to establish standardized treatment protocols and optimize its therapeutic potential.

Conclusion

This review highlights curcumin as a versatile and promising therapeutic agent in the management of a wide spectrum of oral diseases, including oral mucositis, periodontal diseases, recurrent aphthous stomatitis, oral submucous fibrosis, oral lichen planus, and oral potentially malignant disorders. Its clinical efficacy is largely attributed to its multi-targeted mechanisms—anti-inflammatory, antioxidant, antimicrobial, antifibrotic, and anticancer—which act through modulation of key molecular pathways such as NF-κB, COX-2, cytokines, and apoptotic signaling.

Evidence from the included randomized controlled trials demonstrates that curcumin, in various formulations such as mouthwashes, gels, local drug delivery systems, and nanoformulations, provides significant clinical benefits including reduction in inflammation, pain, lesion size, and disease progression. In several conditions, it has shown comparable efficacy to conventional therapies with the added advantage of a favorable safety profile.

However, its clinical translation is limited by poor bioavailability, variability in formulations, lack of standardized dosing regimens, and heterogeneity in study designs. Additionally, most studies are of short duration and involve relatively small sample sizes, which may affect the generalizability of findings.

In conclusion, curcumin holds substantial potential as a safe and effective adjunct or alternative in oral healthcare. Nevertheless, well-designed, large-scale randomized controlled trials with standardized protocols and advanced delivery systems are essential to validate its efficacy and facilitate its integration into routine clinical practice.

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