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Systematic Review

A Comparison of the Efficacy of Non-chemical versus Chemical Cleansers against *Candida* Species on Removable Dental Prostheses: A Systematic Review

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Abstract

Background and objectives: *Candida* species, particularly *Candida albicans*, are major contributors to denture-induced stomatitis because of their ability to form biofilms on removable dental prostheses. Although chemical cleansers are effective, concerns regarding material degradation and mucosal irritation have spurred interest in non-chemical alternatives. This review aims to systematically compare the efficacy of chemical and non-chemical denture cleansers in reducing *Candida* spp. on removable dental prostheses.

Methods: A systematic review was conducted according to the PRISMA 2020 guidelines. Comprehensive searches of PubMed, Scopus, and Web of Science (2003–2025) yielded 624 records. After duplicate removal and screening, 20 studies (10 randomized controlled trials (RCTs) and 10 *in vitro* studies) were included. The risk of bias was assessed using the Cochrane Risk of Bias 2.0 for RCTs and QUIN/SYRCLE tools for *in vitro* studies.

Results: Chemical cleansers such as sodium hypochlorite (0.25–2.5%), chlorhexidine (0.2–2%), and effervescent peroxide tablets achieved 80–100% colony-forming unit reduction in most studies, with some reporting complete biofilm eradication. In contrast, non-chemical agents showed a 40–85% colony-forming unit reduction rate. Chemical cleansers caused increased surface roughness and discoloration in six of the ten studies included. Non-chemical agents preserved material integrity and were preferred by patients for their taste and ease of use. The risk of bias was low to moderate in 80% of the RCTs and low in 10 of the 13 *in vitro* studies.

Conclusions: Chemical denture cleansers are more potent antifungal agents, but they may damage prosthetic materials. Non-chemical cleansers offer safe and moderately effective alternatives to chemical cleansers. A personalized, evidence-based oral hygiene regimen is recommended for patients.

Keywords: Antibacterial agent; Antifungal agent; Chlorhexidine; Denture cleanser; Denture stomatitis; Polymethyl methacrylate; Sodium hypochlorite.

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Introduction

Candida species, particularly *Candida albicans (C. albicans)*, are prominent opportunistic fungal pathogens frequently implicated in denture-related stomatitis in individuals with removable dental prostheses (RDPs). These pathogens readily adhere to the porous surfaces of denture base materials, such as polymethyl methacrylate (PMMA), forming resilient biofilms that pose a significant challenge for disinfection and oral hygiene maintenance.[1–3] The persistence of such biofilms is especially concerning among elderly, immunocompromised, and institutionalized individuals, where *Candida* colonization rates are notably high.[4,5] Maintaining effective denture hygiene is essential to prevent microbial buildup, enhance prosthesis longevity,

and ensure overall oral health. Conventional denture-cleansing strategies typically involve mechanical and chemical methods. Mechanical cleaning, such as brushing, dislodges loosely attached debris but often fails to eliminate well-established *Candida* biofilms.[6,7] Consequently, chemical denture cleansers have been widely employed. These include alkaline peroxide-based tablets, sodium hypochlorite solutions, enzymatic formulations, and chlorhexidine-based agents, all of which act by disrupting biofilm structure and damaging fungal cell membranes, leading to a substantial reduction in microbial load.[1,3,8,9] However, prolonged use of these agents may cause undesirable alterations to the physical properties of denture base materials, such as changes in color stability, increased surface roughness, and reduced hardness, which can, paradoxically, enhance microbial adhesion over time.[9–11] Moreover, patients with mucosal sensitivities may experience adverse effects such as irritation or allergic reactions from regular exposure to chemical agents.[4] Sometimes, even the most effective chemical cleansers fail to completely eliminate *Candida* cells from denture surfaces, allowing residual biofilm to act as a nidus for re-colonization.[12] These limitations have led to the exploration of non-chemical alternatives that are both effective and safer for long-term use.

Non-chemical cleansing approaches include mechanical brushing, microwave irradiation, ultrasonic cleaning, and herbal solutions. Physical disinfection methods, such as microwave and ultrasonic cleaning, have demonstrated efficacy in disrupting *Candida* biofilms without compromising denture integrity.[6,13,14] Several herbal denture cleansers have shown promising antifungal activity.[15–17] They offer several advantages, including reduced cytotoxicity, environmental sustainability, and cost-effectiveness. *In vitro* studies have demonstrated comparable antifungal efficacy of herbal formulations to that of chemical agents, making them viable alternatives for routine denture hygiene.[15,17] Various studies on phenylamines, pyridines, pyrazines, oxadiazoles, and gallate-based compounds that act against *Candida* have been conducted and have elucidated their antioxidant and anti-inflammatory actions.[15,16] Some of these originate from plant sources or are based on structures from *Cnidium officinale*, neem, and marine algae.[15–17] Docking and molecular dynamics illustrate the processes by which these compounds bind to *Candida* targets, such as Als3 adhesins and secreted aspartyl proteases, thereby supporting structure-guided development.[16] Thus, it is essential to study agents that restrict fungal growth, block biofilm development, and reduce harmful host responses, with low cytotoxicity and limited effects on denture materials.[4,8,15,18]

This systematic review addresses the limited comparative evidence on the efficacy of chemical and non-chemical denture cleansers in reducing *Candida* species on RDPs. Although several studies have evaluated the antifungal effectiveness of individual cleansing methods, differences in study design, denture materials, and outcome measures have made direct comparisons difficult. The long-term effects on denture base materials have not been consistently reported across studies. A consolidated analysis comparing both types of cleansers based on their antifungal efficacy and impact on denture integrity is needed. This review aims to compare the antifungal efficacy of chemical and non-chemical denture cleansers against *Candida* species on RDPs and evaluate their impact on denture base material integrity. It also aims to assess patient-centered outcomes, such as safety, compliance, and tolerability of these materials.

Materials and methods

Research question and Population, Intervention, Comparison, Outcome, Study design (PICOS) framework

This systematic review aims to evaluate and compare the antifungal efficacy of non-chemical versus chemical denture cleansers in managing *Candida* species colonization on RDPs. The research question was framed using the PICOS framework to ensure clarity, relevance, and alignment with the study objectives. The research question guiding the review was: *"Among individuals using RDPs, how does the use of non-chemical cleansers compare to chemical cleansers in reducing the colony-forming units (CFUs) of* Candida *species on the acrylic resin portion of the prosthesis?"* This review was registered in the PROSPERO database under the registration number CRD420251106154.

The PICOS criteria were as follows:

- *Population:* Individuals using removable, provisional, or definitive dental prostheses.
- *Intervention:* Use of non-chemical denture cleansers, including physical and herbal cleansing agents.
- *Comparison:* Use of chemical denture cleansers, including peroxide-based, chlorhexidine, sodium hypochlorite, and enzymatic solutions.
- *Outcome:* Reduction in the CFU of *Candida* species, particularly on the acrylic resin surfaces of RDPs.
- *Study design:* Randomized controlled trials (RCTs) and non-randomized clinical trials.

Search strategy

A comprehensive electronic search was conducted using three databases: MEDLINE/PubMed, Web of Science, and Scopus. The search strategy adhered to the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological transparency and reproducibility (Fig. 1). The search covered studies published from January 2003 to April 2025. Boolean operators were used to combine key concepts and improve sensitivity. The keywords used included "*prosthesis,*" "*denture,*" "*acrylic resin,*" "*Candida species*," "*Candida albicans*," "*chemical and non-chemical cleansers*," "*synthetic and natural cleansers*," "*mouthwash and disinfectants*," "*antifungal*," "*anticandidal*," and "*fungicide.*" These terms were searched in combination using Boolean operators (AND, OR) tailored to each database. For the Web of Science, the search included combinations of the terms "*prosthesis*" *OR* "*denture*" *OR* "*acrylic resin*," "*Candida species*" *OR* "*Candida albicans*," and "*chemical and non-chemical cleansers*" *OR* "*synthetic and natural cleansers*" *OR* "*mouthwash and disinfectants*" *OR* "*antifungal*" *OR* "*anticandidal*" *OR* "*fungicide.*" For MEDLINE/PubMed, the same search logic was applied using parentheses and Boolean operators to connect the search fields. In Scopus, slightly modified Boolean combinations, such as "*chemical AND non-chemical cleansers*" and "*mouthwash AND disinfectants*," were applied. Only full-text articles published in English were considered.

Eligibility criteria

The inclusion criteria for this systematic review encompassed clinical studies, such as RCTs, non-randomized clinical trials, and observational designs, including cross-sectional studies, as well as *in vitro* investigations evaluating the antifungal efficacy of chemical and/or non-chemical denture cleansers against *Candida* species on RDP materials. Eligible studies involved either human participants using RDPs or laboratory models simulating clinical conditions and specifically reported outcomes related to *Candida* reduction. Only articles published in English from 2003 onward were considered. Studies were excluded if they were published before 2003, not in English, used denture cleansers without assessing their effect on *Candida*, involved animal models, or lacked the use of either chemical or non-chemical cleansers specifically targeting

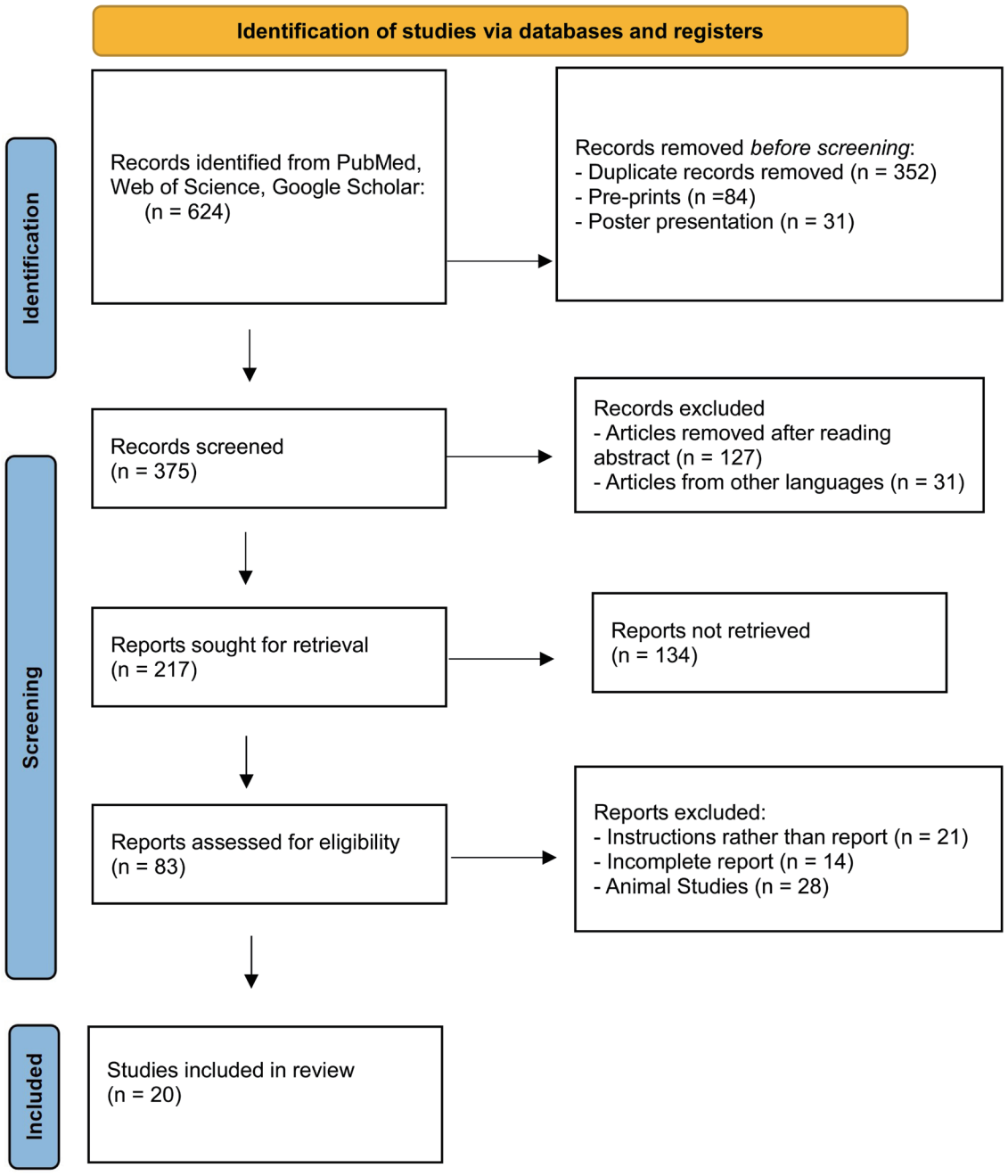

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart for the review (2020).

Candida spp. Case reports, pilot studies without structured methods, systematic reviews, editorials, conference abstracts, letters to the editor, theses, dissertations, and other non-peer-reviewed gray literature were also excluded.

Selection process and data extraction

Duplicate records were removed manually. Title and abstract screening were independently conducted by three reviewers (MWN, AZA, and BAA) based on predefined eligibility criteria. Of the 624 articles, only 20 were included in the present review (Fig. 1). Full texts of potentially relevant studies were retrieved and assessed for inclusion. Any discrepancies among the reviewers were resolved through discussion. Data were extracted using a standardized form, capturing details such as author names, year of publication, study design, sample size, type of denture and cleanser used, concentration and duration of cleanser application, type of *Candida* spp. identified, outcome measures (primarily CFU reduction), and results. Each reviewer independently extracted the data, and consensus was reached through cross-verification.

Data synthesis and quality assessment

The review included a qualitative synthesis of the selected studies

due to wide variation in cleanser types (chemical and non-chemical), treatment durations, study models (clinical and *in vitro*), denture base materials, and outcome assessment methods. The antifungal efficacy of chemical and non-chemical cleansers was compared across different settings. Three reviewers (MAA, MHA, and AMG) independently assessed the methodological quality and risk of bias using validated tools. The Cochrane Risk of Bias 2.0 (ROB2) tool was applied to RCTs,[19] evaluating domains such as randomization, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. The Newcastle–Ottawa Scale was used to assess non-randomized clinical trials,[20] focusing on the selection, comparability, and outcome domains. For *in vitro* studies, the QUIN tool was used to evaluate methodological quality across 12 criteria,[21] including study design, sample preparation, microbial standardization, and outcome assessment, while the modified SYRCLE Risk of Bias tool was applied to assess selection, performance, detection, attrition, and reporting biases.[22] Each study was rated as having low, moderate, or high risk of bias, and only those with low-to-moderate risk were included in the final synthesis. The systematic review adhered to the PRISMA 2020 guidelines, and a flow diagram (Fig. 1) was generated to detail the study selection process.

Results

Study characteristics

Table 1 summarizes the findings of 20 studies that evaluated the antifungal efficacy of chemical and non-chemical denture cleansers against *Candida* species on RDPs.[2,3,5–7,9–12,14–16,18,23–29] The study designs included both *in vitro* and clinical trials, with sample sizes ranging from 24 to 180 specimens or participants. The chemical agents investigated included sodium hypochlorite, chlorhexidine, peroxide-based tablets (e.g., Corega, Fittydent), enzymatic cleansers, and glutaraldehyde.[3,7,9,10,14,25] Non-chemical methods included ultrasonic cleaning, brushing, microwave disinfection, and herbal extracts such as *Cnidium officinale*, Triphala, and *Turbinaria conoides*.[6,15,28,29] Protocols varied in terms of concentration (0.25–4%), exposure duration (3 min to overnight), and frequency (single use to 180 days). *C. albicans* was the most tested species, although some studies included mixed strains.[5,24] The diagnostic tools used included CFU counts, quantitative polymerase chain reaction, scanning electron microscopy, and 2bRAD-M sequencing.[3,5,18,29] Only a limited number of studies examined mucosal irritation or changes to denture base materials.[16,26] The controls commonly used sterile water or saline.[2,14]

Table 2 provides a comparative analysis of antifungal efficacy, material effects, and tolerability between chemical and non-chemical denture cleansers based on 20 studies.[2,3,5–7,9–12,14–16,18,23–29] Chemical agents such as sodium hypochlorite, chlorhexidine, Fittydent®, and Polident® showed superior *C. albicans* reduction, with several studies reporting complete elimination (0 CFU).[12,14,25] Non-chemical options such as vinegar, Triphala, ricinus oil, and herbal extracts also showed antifungal activity but were generally less effective.[12,15,24,28] Some studies found no statistically significant difference ($P > 0.05$) between select chemical and non-chemical agents.[24] Hypochlorite and 3D-printed materials were more prone to surface roughness and discoloration,[9,10,14] while natural cleansers such as *Cnidium officinale* and CPC-Mont preserved material properties.[16,26] Most clinical studies reported good patient compliance and minimal side effects.[24,29] Alfouzan *et al*.[14] and Lee *et al*.[16] observed effective antimicrobial zones with minimal material alteration using natural cleansers.

Only five of the 20 studies used an overnight soaking time of 6–8 h.[5,18,28,29] Most were dependent on short immersion periods of 3–20 min based on product directions and not on the process of denture cleaning. Short cycles can make slower-acting non-chemical agents, such as herbal extracts, appear less effective because they often require longer contact to reach and disrupt the biofilm, thereby facilitating the use of denture cleansers (Table 3).[2,3,5–7,9–12,14–16,18,23–29] Thirteen of the 20 included studies were controlled *in vitro* experiments that reduced clinical confounders and provided high internal validity by standardizing the formation of biofilm, concentration of the cleanser, exposure time, and type of material.[1–3,6,9–12,14,23,26–28]

Quality assessment

Table 4 outlines the methodological quality of the included RCTs, assessed using the Newcastle–Ottawa Scale.[5,7,15,18,20,24,25,29] Studies were rated as high quality (≥9/10), showing strong performance across the selection, comparability, and outcome domains. Lim *et al*.[29] received the highest score (10/10), with full stars for selection and outcome and one for comparability. Moderate-quality ratings (7/10) were given to some studies, often due to fewer stars in selection or limited comparability.[18,24,25] Overall, most RCTs included were of moderate to high quality, adding credibility to the synthesized findings.

Table 5 presents the quality assessment of the 13 *in vitro* studies using the QUIN tool, which evaluates 12 methodological domai ns.[2,3,6,9–12,14,16,21,23,26–28] The scores ranged from 62.5% to 95.83%. Ten studies scored ≥75%, indicating a low risk of bias, while three were rated as medium risk.[3,9,27] The top-scoring studies each scored 95.83%, demonstrating strong internal validity.[16,28]

Figure 2 shows antifungal activity and material effects of chemical and non-chemical denture cleansers.

Figure 3 summarizes the ROB2 assessment across the five bias domains in the included RCTs.[19] Only one study showed a low risk across all domains.[29] Three studies demonstrated a low risk in domains D3 (missing outcome data) and D4 (outcome measurement).[7,18,25] Others showed "some concerns" in D2 (deviations from intended interventions) and D5 (selection of reported results), often due to incomplete reporting or protocol deviations. Domain D1 (randomization process) showed unclear or insufficient details in some studies, indicating potential selection bias.[24] Most trials showed a low-to-moderate risk of bias, with the greatest concerns centered on randomization and reporting practices. The ROB2 evaluation reflected generally acceptable methodological quality but emphasized the need for more rigorous trial design and transparent reporting in future clinical research on denture cleanser efficacy.

Figure 4 presents the overall percentage distribution of risk-of-bias judgments across all ROB2 domains in the included RCTs.[19] Most studies showed a low risk of bias in D3 (missing outcome data) and D4 (outcome measurement), indicating adequate data handling and outcome assessment. However, D1 (randomization process) and D5 (selective reporting) displayed a smaller proportion of studies with "some concerns" or insufficient detail, suggesting possible selection and reporting biases. D2 (deviations from intended interventions) revealed moderate concerns in several studies, reflecting inconsistencies in adherence to interventions. Although most included trials demonstrated a low risk across key domains, these results highlight methodological gaps in trial design and reporting. Improved randomization procedures and transparent reporting practices are essential to enhance the reliability of the evidence concerning the antifungal efficacy of

Table 1. Summary of the included studies presenting key characteristics, denture cleanser types (chemical or non-chemical), protocols used, *Candida* species tested, and other methodological features relevant to the systematic review

Author/ Year	Study design	Sample size	Type of prosthesis	Type of denture cleanser	Cleansing protocol (frequency, duration, concentration)	Type of *Candida* spp. assessed	Diagnostic/Detection method	Control/ Comparator used	Follow-up Period
Kumar *et al*., 2012[12]	*In vitro* experimental	50 acrylic resin specimens (10 per group)	Heat-cured acrylic denture base resin	Commercial: Fittydent® (tablet), Clinsodent® (powder); Household: Vinegar (4% acetic acid), diluted vinegar (50% vinegar + 50% water)	Immersion for 8 h at room temperature in denture cleanser solution; solutions prepared per manufacturer instructions or household concentrations; specimens washed post-immersion	*Candida albicans*	Microscopic counting of adherent *Candida* cells stained with crystal violet under ×40 magnification	Water (control group)	Single 8-h immersion simulating overnight soak
Machado *et al*., 2012[23]	*In vitro* experimental	50 specimens (10 per material)	Denture base resin and relining materials (Lucitone 550, Tokuyama Rebase II, New Truliner, Ufigel Hard, Trusoft, Sofreliner)	Chemical: 4% Chlorhexidine immersion; Non-chemical: Microwave irradiation (650W, 6 min)	Groups subjected to either 2 cycles or 7 cycles of disinfection: (i) chlorhexidine immersion 1 min brushing + 10 min soak + 3 min water rinse; (ii) microwave irradiation 6 min in water; controls immersed in water for 7 days at 37°C	Not specified for *Candida* species (focus on surface roughness)	Surface roughness (Ra, µm) by profilometry; statistical comparison of pre- and post-treatment	Water immersion only (control group)	2 cycles, 7 cycles disinfection; 7 days immersion for controls
Duyck *et al*., 2016[18]	Cross-over randomized clinical trial	13 older adults	Maxillary and mandibular acrylic removable dentures	Mechanical: Brushing and Ultrasonic cleaning; Chemical: Alkaline peroxide-based effervescent cleansing tablet (Corega anti-bacteria)	4 test conditions for 5 consecutive days each with 2-day washout between: (i) brushing + water immersion; (ii) brushing + water + cleansing tablet; (iii) ultrasonic + water immersion; (iv) ultrasonic + water + cleansing tablet; Ultrasonic cleaning 15 min at 35 kHz; Tablet immersion overnight as per manufacturer	*Candida albicans*	Quantitative PCR analysis; analogue denture plaque scoring with erythrosine disclosing	Baseline (post mechanical cleaning and disinfection)	Each test condition lasted 5 days
Badaró *et al*, 2017[24]	Randomized, double-blind, crossover clinical trial	64 participants (24 with candidiasis, 40 without)	Conventional maxillary complete dentures fabricated with heat-activated acrylic resin	Chemical: 0.25% NaOCl (S1), 0.5% NaOCl (S2); Non-chemical: 10% *Ricinus communis* oil solution (S3); Control: 0.85% saline solution (S4)	*Candida* spp. including *C. albicans* and others in oral biofilm	DNA-Checkerboard hybridization; clinical visual scale for candidiasis remission; photographic analysis	Saline solution (S4)	Each solution used for 7 days, with 7-day washout; total approx. 4 treatment periods per participant	

(continued)

Table 1. *(continued)*

Author/ Year	Study design	Sample size	Type of prosthesis	Type of denture cleanser	Cleansing protocol (frequency, duration, concentration)	Type of *Candida* spp. assessed	Diagnostic/Detection method	Control/ Comparator used	Follow-up Period
Porwal *et al.*, 2017[9]	*In vitro* experimental	60 specimens (20 per resin group)	Denture base resins: Conventional heat cure (Group I), High impact heat cure (Group II), Polyamide (Group III)	Chemical: 0.5% Sodium hypochlorite (Vishal Dentocare Pvt. Ltd.), 3.8% Sodium perborate (Vovantis Laboratories Pvt. Ltd.)	Daily immersion of specimens in respective cleanser for 10 min at room temperature for 180 consecutive days; thorough washing and storage in distilled water between immersions	Not specified (focus on physical properties, no microbial test)	Color measured via spectrophotometer (CIELAB L*a*b* system), Surface roughness (Ra) by profilometer, Hardness by Vickers hardness test	Control: baseline pre-immersion measurements	180 days (daily immersion)
Mojarad *et al.*, 2017[6]	*In vitro* experimental	72 mandibular dentures (6 per group per microorganism)	Complete mandibular dentures	Chemical: Corega tablets; Chemical: 2% glutaraldehyde; Mechanical: brushing with distilled water; Physical: Microwave irradiation 650 W	Group 1: Brushing 5 min with sterile water + 5 min immersion in sterile water Group 2: 2% glutaraldehyde immersion 10 min Group 3: Corega tablet immersion in 200 mL of water at 37°C for 15 min Group 4: Microwave irradiation at 650W for 3 min (immersed in 150 mL sterile water)	*Staphylococcus aureus* and *Pseudomonas aeruginosa*	Colony-forming unit (CFU) counting on nutrient agar plates after 48 h incubation; turbidity assessed after 7 days incubation in broth	Negative control: sterile specimens Positive control: contaminated, no disinfection	48 h for CFU count; 7 days for turbidity evaluation
Sushma *et al.*, 2017[15]	Randomized clinical trial	60 complete denture wearers (2 groups of 30 each)	Complete dentures (heat polymerized acrylic resin)	Non-chemical: Triphala churna (herbal powder) Chemical: 0.2% chlorhexidine gluconate mouthwash	Group I: Chlorhexidine applied with cotton, rubbed over denture surface daily for 30 days, followed by water rinse Group II: Triphala churna scrubbed gently on denture surface daily for 30 days, followed by water rinse	*Candida albicans*	Swabs cultured on Sabouraud dextrose agar, incubated 72 h at 37°C; CFUs counted; confirmed by germ tube test and Gram stain	Baseline (before intervention)	30 days
Han *et al.*, 2020[3]	*In vitro* experimental study	45 PMMA disks (9 disks per group × 5 groups)	Heat-cured PMMA acrylic resin disks	Chemical cleansers: Clene®, Polident®, 3% sodium bicarbonate (NaHCO3), PBS, filter-sterile tap water	Daily immersion of disks in cleansing solutions for 4 weeks with daily solution replacement. Concentrations: Clene® and Polident® tablets dissolved as per manufacturer instructions; 3% NaHCO3 freshly prepared; PBS and water as controls	*Candida albicans* (ATCC 90028)	CFUs counting; MTT assay for biofilm quantification; SEM imaging and surface roughness measurement by stylus method	PBS and filter-sterile tap water controls	4 weeks of incubation with daily solution change

(continued)

Table 1. *(continued)*

Author/ Year	Study design	Sample size	Type of prosthesis	Type of denture cleanser	Cleansing protocol (frequency, duration, concentration)	Type of *Candida* spp. assessed	Diagnostic/Detection method	Control/ Comparator used	Follow-up Period
Pandey *et al*., 2021[25]	Randomized controlled trial	80 denture wearers divided into 4 groups (20 each)	Complete upper dentures (heat-cured acrylic resin)	Chemical: 1) 4% sodium hypochlorite (Sno Wite); 2) Effervescent sodium metaborate tablet (Klinzar); 3) 0.12% chlorhexidine gluconate (Lacer Chlorhexidine); 4) Control: distilled water	Dentures brushed unilaterally with sterile toothbrush + sterile saline rinse; saliva solution collected and diluted; 5 mL denture cleanser added to diluted solution and incubated 20 min; cultured on Sabouraud's dextrose agar; 48 h incubation	*Candida albicans* and non-albicans species	CFUs counted after 48h culture; confirmed by Gram stain and germ tube test	Distilled water group (control)	Single time point cross-sectional culture
Asahara *et al*., 2022[26]	*In vitro* + *in vivo* animal study	3 disks per condition (*in vitro*), 5 hamsters (*in vivo*)	Tissue conditioner disks (diameter 20 mm, thickness 1.6 mm)	Non-chemical antimicrobial tissue conditioner containing CPC-montmorillonite (CPC-Mont)	Immersed in PBS at 37°C for 7, 14, 21, and 28 days; antimicrobial tests conducted at each time point; *in vivo* oral mucosa irritation test with daily application for 14 days	*Candida albicans* (IFM40009)	CFU counts on selective agar plates after incubation; histological evaluation of oral mucosa irritation in hamster cheek pouches	CPC-Mont (−) tissue conditioner (no antimicrobial)	Up to 28 days (*in vitro*), 14 days (*in vivo*)
Nishi *et al*., 2022[5]	Cross-sectional survey	77 edentulous nursing home residents (152 dentures: 75 upper, 77 lower)	Complete dentures (heat-cured acrylic resin)	Chemical: Enzyme-containing Polident®, Toughdent®, Pika® (*Candida*-dissolving enzyme) and others; Mechanical: denture brushing	Participants self-cleaned dentures using various regimens assessed via questionnaire and direct observation; Majority-soaked dentures overnight (~8 h) in cleansers; Frequency varied: daily (38.2%), 3–4 times/week (9.2%), 1–2 times/week (16.4%), never (36.2%)	*Candida albicans*, *C. glabrata*, *C. tropicalis*, others	CFUs counted on CHROMagar *Candida* after 48 h incubation at 37°C; species identified by colony morphology and color; log (CFU+1/mL) calculated	No explicit negative control; comparisons based on frequency/type of cleanser use	Single time-point cross-sectional measurement
Rajendran *et al*., 2022[7]	Randomized controlled trial	60 removable partial denture wearers (20 per group)	Removable partial dentures fabricated with PMMA resin (no metal framework)	Group 1: Sterile water + denture brush (negative control); Group 2: Soap + denture brush; Group 3: Effervescent denture cleansing tablet (Fittydent) + denture brush	Daily cleaning once per day for 15 days. Group 1: brushing with sterile water for 3 min; Group 2: brushing with soap for 3 min; Group 3: tablet dissolved in 200 mL warm water soaking for 10 min, followed by brushing for 3 min	*Candida albicans*	Swab samples cultured on Sabouraud's dextrose agar (SDA) for 48 h; colonies counted under stereomicroscope; confirmed by Gram stain, germ tube test, cornmeal agar	Group 1: sterile water + brushing	Baseline (day of insertion) and after 15 days of cleaning

(continued)

Table 1. *(continued)*

Author/ Year	Study design	Sample size	Type of prosthesis	Type of denture cleanser	Cleansing protocol (frequency, duration, concentration)	Type of *Candida* spp. assessed	Diagnostic/Detection method	Control/ Comparator used	Follow-up Period
Alfouzan *et al.*, 2023[14]	*In vitro* experimental	180 discs	PMMA discs fabricated by Conventional, CAD/CAM milling, and 3D printing	Chemical cleansers: Fittydent tablets, 0.2% CHG, 2% CHG, 0.5% NaOCl, 1% NaOCl	Immersed once in each cleanser solution: Fittydent - 5 min; 0.2% CHG - 20 min; 2% CHG - 5 min; 0.5% NaOCl - 20 min; 1% NaOCl - 10 min (per manufacturer's instructions)	*Candida albicans* (ATCC 10231)	CFU/mL after biofilm formation; Confocal Laser Scanning Microscopy; Scanning Electron Microscopy	Distilled water (immersion 20 min) control group	Single immersion (immediate post-treatment assay)
Takhtdar *et al.*, 2023[10]	*In vitro* experimental study	72 specimens (24 per fabrication group; 8 per cleanser subgroup)	PMMA denture base discs fabricated by: 1) Conventional heat-polymerizing; 2) CAD/CAM additive (3D printing); 3) CAD/CAM subtractive (milling)	Chemical cleansers: 1) 1% sodium hypochlorite; 2) Corega bioactive oxygen tablet; Control: Distilled water	Immersion protocol simulating 180 days of clinical use: 30 cycles daily of 3-min immersion, rinsing and fresh solution renewal (total 6 days of cycles simulating 180 days)	Not assessed (study focused on material properties, no microbiological testing)	Not applicable (no *Candida* spp. testing performed)	Distilled water (control)	6 days of immersion simulating 180 days of clinical use
Wibawaningtyas *et al.*, 2017[27]	*In vitro* laboratory-based experiment	30 thermoplastic nylon samples (10×10×1 mm), divided into 6 groups (5 treatment groups + 1 control, n = 5 per group)	Thermoplastic nylon (Valplast)	Non-chemical: Clove flower extract (Syzygium aromaticum) at 0.8%, 1.0%, 1.2%, 1.4%, and 1.6% concentrations	Immersion in respective clove extract concentrations for 12 days continuously at room temperature; control group immersed in sterile aquades (distilled water)	Not assessed	Light intensity measured by densitometer	Control: Sterile aquades	12 days of immersion
Varsha *et al.*, 2023[28]	*In vitro* experimental	24 acrylic resin samples (12 per group)	Heat-cured acrylic resin discs (10 mm diameter, 2 mm thick)	Chemical: Commercial denture cleanser tablet (Fittydent). Non-chemical: Hexane extract of marine seaweed *Turbinaria conoides*	Immersion of specimens for 8 h at room temperature in 1 mL solution (Fittydent dissolved in 100 mL distilled water; seaweed extract diluted 5 mL in 95 mL distilled water).	*Candida albicans*	CFUs by serial dilution and pour plate method; 24 h incubation at 37°C; colony counting and statistical analysis with t-test	Baseline (before treatment)	Single time point

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Table 1. *(continued)*

Author/ Year	Study design	Sample size	Type of prosthesis	Type of denture cleanser	Cleansing protocol (frequency, duration, concentration)	Type of *Candida* spp. assessed	Diagnostic/Detection method	Control/ Comparator used	Follow-up Period
Lee *et al*., 2024[16]	*In vitro* + *in vivo* biological safety testing	Acrylic resin disks (10 mm × 10 mm × 0.1 mm), n = 3 per test	Heat-cured acrylic resin denture base	Chemical: Denture cleanser formulated with *Cnidium officinale* extract + 1% cocamidopropyl betaine (natural surfactant); concentrations: 100 and 150 µg/mL extract	Immersion of acrylic disks in 2 mL cleanser solution daily for 7 and 30 days at 25 ± 1 °C; solutions refreshed daily. Agar diffusion for antimicrobial zones: 20 µL solution per disk, incubated 24 h	*Candida albicans* (ATCC 10231)	Inhibition zone assay on agar plates; LIVE/DEAD fungal viability staining using confocal microscopy; agar overlay cytotoxicity assay; oral mucosal irritation in hamsters	Control: cleanser without *Cnidium officinale* extract	7 days and 30 days immersion for physical tests; 24 h incubation for antimicrobial assays; 4 h mucosal irritation
Echhpal *et al*., 2024[2]	*In vitro* experimental	30 specimens (10 per group)	Denture base resins: Milled PMMA, Conventional heat cured, Printed resin	Chemical: Secure denture cleansing tablets, Polident powder, Clinsodent powder, Table salt (iodized)	Single immersion in cleanser solution per manufacturer instructions: Secure tablet, Polident, Clinsodent - concentration as per label; Table salt solution prepared fresh. Incubation time: Not explicitly stated but standard protocol for tablet immersion (~5–10 min)	*Candida albicans* (biofilm formed over 5 days)	CFU counting on Sabouraud Dextrose agar after 48 h incubation	Untreated control specimens	Single treatment; biofilm formation 5 days prior
Alfahdawi, 2025[11]	*In vitro* experimental	90 specimens (9 groups × 10 each)	Heat-polymerized PMMA denture base specimens, disc-shaped (10 × 10 × 2 mm)	Chemical (Corega oxygenating tablets - enzymatic, sodium hypochlorite 0.5%), Abrasive, Non-abrasive cleansers	Daily immersion for simulated 90 and 180 days; concentrations per manufacturer instructions; cleaners: G1 (abrasive), G2 (enzymatic), G3 (chemical), G4 (non-abrasive)	*Candida albicans*	Agar diffusion (Kirby-Bauer zone of inhibition) method	Distilled water subgroup	90 and 180 days simulated
Lim *et al*., 2025[29]	Prospective, single-blind, block-randomized two-period crossover clinical trial	56 community-dwelling older adults	Removable acrylic dentures (complete and extensive partial)	Chemical: enzymatic peroxide-based denture cleanser (Polident 3 min™); Combined with portable ultrasonic cleaner for test arm; Control used chemical cleanser with brushing	Test arm: Daily ultrasonic cleaning with denture cleanser solution (225 mL water + 1 tablet), ultrasonication at 45 kHz for 15 min every night. Control arm: Denture immersed in same cleanser solution for 15 min, followed by brushing for 30 seconds, daily	Not specified to species, general denture microbiome analysis with focus on *Candida albicans*	2bRAD-M metagenomic sequencing for species-resolved microbial profile	Control arm: chemical cleanser + manual brushing	Two intervention periods of 3 months each, separated by a 2-week washout; total trial duration ~8 months

ATCC, American Type Culture Collection; CFU/mL, colony-forming units per milliliter; CHG, chlorhexidine gluconate; CLSM, confocal laser scanning microscopy; CPC-Mont, cetylpyridinium-montmorillonite; MTT, tetrazolium reduction assay for metabolic activity; PBS, phosphate-buffered saline; PMMA, polymethyl methacrylate; qPCR, quantitative polymerase chain reaction; RPD, removable partial denture; SDA, Sabouraud dextrose agar; SEM, scanning electron microscopy.

Table 2. Comparative analysis of antifungal efficacy (as measured by CFU reduction) between non-chemical and chemical denture cleansers, alongside material safety, patient tolerability, and risk of bias scores for each study

Author/ Year	Non-chemical cleanser used	Chemical cleanser used	CFU reduction in non-chemical group	CFU reduction in chemical group	Statistical significance (*P*-value or CI)	Effect on denture material (surface roughness, color stability, etc.)	Patient compliance/ Adverse effects reported
Kumar *et al.*, 2012[12]	Vinegar (4% acetic acid), diluted vinegar (50%)	Fittydent® (tablet), Clinsodent® (powder)	Vinegar: 1.02 ± 0.85 % cells; diluted vinegar: 5.00 ± 5.31 % cells remaining	Fittydent®: 0.22 ± 0.32 % cells; Clinsodent®: 0.28 ± 0.32 % cells remaining	ANOVA $P < 0.001$; Tukey's test: Fittydent® > Clinsodent® > Vinegar > Diluted vinegar	Not assessed in this study; emphasis on antimicrobial efficacy only	Not reported
Machado *et al.*, 2012[23]	Microwave irradiation (650W, 6 min)	4% Chlorhexidine immersion (1 min brushing + 10 min soak)	Not measured (study focused on roughness, not microbial counts)	Not measured (study focused on roughness, not microbial counts)	Not applicable for microbial data; surface roughness significant changes tested via Student's t test ($P < 0.05$)	Microwave disinfection caused significant increases in roughness for New Truliner (NT) and severe surface damage to Trusoft (T); Chlorhexidine caused increases in roughness for Ufigel Hard (UH) and Sofreliner (S); no significant roughness change for Lucitone (L) and Tokuyama Rebase II (TR)	No patient data (*in vitro* study)
Duyck *et al.*, 2016[18]	Mechanical cleaning only (brushing or ultrasonic, no tablet)	Mechanical cleaning + alkaline peroxide cleansing tablet immersion overnight	Brushing + water (B-T): 1.80 ± 2.84 (*Candida albicans*). Ultrasonic + water (U-T): 1.24 ± 2.41 (*Candida albicans*)	Brushing + tablet (B+T): 0.36 ± 1.31 (*Candida albicans*). Ultrasonic + tablet (U+T): 1.05 ± 2.01 (*Candida albicans*)	No significant difference in *Candida albicans* counts between test conditions ($P > 0.05$)	Not reported in study; however, ultrasonic cleaning was noted as practical for institutional use; tablet immersion reduces total bacterial load but not *Candida* specifically	No adverse effects reported; study conducted in institutional setting with researchers performing cleaning
Badaró *et al.*, 2017[24]	10% *Ricinus communis* oil solution (S3)	0.25% and 0.5% sodium hypochlorite (S1, S2)	S3 showed 50% remission of candidiasis; antimicrobial activity comparable to 0.25% NaOCl; effective reduction in biofilm microbial counts	0.25% NaOCl showed 46% remission: 0.5% NaOCl similar antimicrobial effect to 0.25%	No statistically significant difference between S3 and S1 ($P > 0.05$)	Not evaluated in this study; literature suggests low toxicity and good biocompatibility for *Ricinus communis*; hypochlorite is known to cause material degradation at higher concentrations	All solutions well accepted by patients; no reported adverse effects or taste/ odor complaints during 7-day use

(continued)

Table 2. *(continued)*

Author/ Year	Non-chemical cleanser used	Chemical cleanser used	CFU reduction in non-chemical group	CFU reduction in chemical group	Statistical significance (*P*-value or CI)	Effect on denture material (surface roughness, color stability, etc.)	Patient compliance/ Adverse effects reported
Porwal *et al*., 2017[9]	None	0.5% Sodium hypochlorite; 3.8% Sodium perborate	Not applicable	Not applicable	Not applicable	Color: Polyamide showed the highest color change (ΔE up to 2.923 in sodium perborate); Surface roughness: Increased in all groups; conventional heat cure exceeded clinically acceptable roughness (Ra > 0.2 µm); Hardness: Decreased in all resins; conventional heat cure showed the greatest hardness loss (up to −3.905 VHN)	No patient data (*in vitro* study); no adverse effects reported
Mojarad *et al*., 2017[6]	Mechanical brushing (5 min)	2% Glutaraldehyde (10 min immersion), Corega tablets (15 min immersion)	Brushing group: *S. aureus*: $1.96 \times 10^3 \pm 2.5 \times 10^2$; *P. aeruginosa*: $1.56 \times 10^3 \pm 3.1 \times 10^2$	2% Glutaraldehyde & Corega groups: 0 CFU for both bacteria	$P < 0.001$ for difference between brushing and chemical/ physical methods	Not reported in this study; previous literature reports possible effects of microwave on denture materials, but 3-min irradiation is generally safe	Not reported (*in vitro* study)
Sushma *et al*., 2017[15]	Triphala churna (herbal scrub)	0.2% Chlorhexidine gluconate (cotton applied)	Before: 664.00 ± 355.24; After: 379.37 ± 246.62	Before: 623.30 ± 315.45; After: 424.96 ± 283.19	Both groups $P = 0.00$ (significant reduction); Between groups $P = 0.50$ (no significant difference)	Not assessed directly; no reports of denture material effects in study	Participants reportedly adhered; no adverse effects reported
Han *et al*., 2020[3]	3% Sodium bicarbonate (NaHCO3)	Clene®, Polident®	67.54% reduction (NaHCO3)	Clene®: 98.27%, Polident®: 100% reduction	Clene® and Polident® significantly more effective than NaHCO3 and PBS ($P < 0.05$)	Surface roughness (Ra) after treatment: Clene®: 0.12 ± 0.03 µm; Polident®: 0.12 ± 0.04 µm; NaHCO3: 0.12 ± 0.04 µm; No significant differences among groups ($P > 0.05$)	No adverse effects assessed (*in vitro*); cleansers did not alter surface morphology or roughness based on SEM and stylus measurements
Pandey *et al*., 2021[25]	None (control: distilled water)	4% sodium hypochlorite (Sno Wite); sodium metaborate (Klinzar); 0.12% chlorhexidine gluconate (Lacer Chlorhexidine)	Control: *Candida* detected in 65% cases, CFUs up to 6,000	Sodium hypochlorite: No *Candida* CFUs detected (0/20 cases). Sodium metaborate: *Candida* CFUs detected in 1 case (5%). Chlorhexidine: *Candida* CFUs detected in 1 case (5%)	Sodium hypochlorite significantly better than control ($P = 0.000$). Both sodium metaborate and chlorhexidine significantly better than control ($P = 0.000$)	Not assessed in this study	No adverse effects reported (*in vivo* RCT, 80 participants)

(continued)

Table 2. *(continued)*

Author/ Year	Non-chemical cleanser used	Chemical cleanser used	CFU reduction in non-chemical group	CFU reduction in chemical group	Statistical significance (*P*-value or CI)	Effect on denture material (surface roughness, color stability, etc.)	Patient compliance/ Adverse effects reported
Asahara *et al.*, 2022[26]	CPC-Mont tissue conditioner (non-chemical antimicrobial agent)	None (control: CPC-Mont (−))	Adherent *C. albicans*: (4.7 ± 0.8) ×10^5 CFU (day 0)	Adherent *C. albicans*: (1.6 ± 0.5) ×10^3 CFU at 7 days (approx. 99.7% reduction vs. CPC-Mont (−))	Antimicrobial activity value log (CFU) ≥ 2.0 indicating ≥99% reduction per JIS Z 2801/ ISO 22196 standard	No oral mucosa irritation observed in vivo; no adverse histological findings after 14-day hamster application; material physical properties maintained (no mention of roughness or color change)	No irritation or adverse effects observed in hamster cheek pouch model (ISO 10993-10 compliant)
Nishi *et al.*, 2022[5]	Denture brushing only	Daily use of enzyme-containing denture cleansers (Polident®, Toughdent®, Pika®)	Brushing-only group: 3.21 (1–2 times/ week) to 3.02 (never) log CFU	Daily cleanser use: 0.94 (lowest) log CFU; Pika® cleanser showed 0.00 log CFU (complete elimination)	Frequency of cleanser use significant ($P < 0.001$); cleanser product significant ($P < 0.01$); soaking time significant ($P < 0.01$)	Not assessed in this study; mostly overnight soaking regimen; no reported adverse effects	Participants self-reported cleaning methods; no adverse events reported
Rajendran *et al.*, 2022[7]	Sterile water + brushing	Soap + brushing; Effervescent tablet + brushing	Group 1 (water): Baseline 1,945.47, 15 days 1,625.33 CFU (no significant reduction; $P = 0.065$)	Group 2 (soap): Baseline 2,236, 15 days 1,945.47 CFU (significant reduction; $P = 0.046$). Group 3 (tablet): Baseline 2,271, 15 days 735 CFU (highly significant reduction; $P = 0.000$)	One-way ANOVA between groups $P = 0.004$; Tukey post hoc shows Group 3 vs. Group 1 mean difference 1210.99 CFU; $P = 0.001$	Not assessed in this study	Participants followed instructions strictly; compliance ensured via checklist and reminders; no adverse events reported
Alfouzan *et al.*, 2023[14]	Clove flower extract at various concentrations (0.8% to 1.6%)	None	Not tested	Not tested	One-way ANOVA showed $P = 0.174$ (>0.05); no significant difference in color change	Slight darkening observed at higher concentrations; no statistically significant color changes compared to control	Not applicable (*in vitro* study); no adverse effects reported
Takhtdar *et al.*, 2023[10]	*Turbinaria conoides* hexane extract	Fittydent denture cleanser tablet	Dilution 10^{-2}: 214.17 ± 5.606 CFU; Dilution 10^{-3}: 44.17 ± 6.422 CFU	Dilution 10^{-2}: 279.17 ± 5.340 CFU; Dilution 10^{-3}: 73.42 ± 7.305 CFU	$P < 0.001$ for both dilutions 10^{-2} and 10^{-3} (significant)	Not assessed in study	Not applicable (*in vitro* study)

(continued)

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Table 2. *(continued)*

Author/ Year	Non-chemical cleanser used	Chemical cleanser used	CFU reduction in non-chemical group	CFU reduction in chemical group	Statistical significance (*P*-value or CI)	Effect on denture material (surface roughness, color stability, etc.)	Patient compliance/ Adverse effects reported
Wibawaningtyas *et al*., 2017[27]	Fittydent cleansing tablets	0.2%, 2% CHG; 0.5%, 1% NaOCl	Conventional: 17.2 ± 13.6; CAD/CAM: 2.2 ± 1.6; 3D: 32.1 ± 22.6 (*C. albicans*). Conventional: 35.7 ± 25.6; CAD/CAM: 16.3 ± 19.5; 3D: 92.3 ± 126.2 (S. mutans)	All chemical cleansers (2% CHG, 0.5% NaOCl, 1% NaOCl) showed 0 ± 0.0 CFU/mL. All chemical cleansers showed 0 ± 0.0 CFU/mL for S. mutans	*C. albicans*: $P = 0.003$ (significant difference between Fittydent and chemicals). S. mutans: $P = 0.017$ (Fittydent vs. others significant)	Pre-treatment roughness: Conventional 0.291 ± 0.13; CAD/CAM 0.155 ± 0.04; 3D 0.537 ± 0.17. Post-treatment roughness increased for all: 3D highest 0.690 ± 0.08 µm; chemicals increased surface roughness. Surface roughness increase significant post-treatment ($P < 0.05$); 2% CHG showed lowest roughness increase except 3D-printed	*In vitro* study, no patient data; chemical cleansers are effective but increase surface roughness, which may affect long-term prosthesis; Fittydent less effective antimicrobial
Varsha *et al*., 2023[28]	None (no non-chemical cleanser tested)	Sodium hypochlorite 1% and Corega tablet (chemical)	N/A	N/A	N/A	Sodium hypochlorite significantly increased surface roughness in conventional and subtractive CAD/CAM groups ($P < 0.05$). Corega and distilled water caused no significant roughness change. Additive CAD/CAM group showed the highest color change with all cleansers (noticeable ΔE ~1.5). Subtractive CAD/CAM group showed the lowest color change (trace to slight ΔE < 0.6). Conventional group showed intermediate changes.	Not applicable (*in vitro* study)
Lee *et al*., 2024[16]	Control cleanser (no extract)	Experimental cleanser with *Cnidium officinale* extract (100 and 150 µg/mL)	Control showed no inhibition zone, high fungal viability (no CFU reduction reported)	CN 100: 20 ± 1.8 mm inhibition zone; CN 150: 23.6 ± 1.6 mm inhibition zone; LIVE/DEAD staining showed significantly increased fungal death in CN groups	$P < 0.05$ for inhibition zone size and fungal viability reduction vs. control	No significant differences between CN groups and control in microhardness, surface roughness, color stability, or solubility after 7- and 30-day immersion ($P > 0.05$)	No cytotoxicity in agar overlay assay; no mucosal irritation in hamster cheek pouch test; minimal irritation score (0.3 difference vs. control)

(continued)

Table 2. *(continued)*

Author/ Year	Non-chemical cleanser used	Chemical cleanser used	CFU reduction in non-chemical group	CFU reduction in chemical group	Statistical significance (*P*-value or CI)	Effect on denture material (surface roughness, color stability, etc.)	Patient compliance/ Adverse effects reported
Echhpal *et al*., 2024[2]	Table salt (iodized)	Secure tablet, Polident powder, Clinsodent powder	Conventional: 5.254×10^2 reduction; Printed: 8.920×10^2 reduction; Milled: 7.329×10^2 reduction	Secure: Conventional 8.33×10^2; Printed 9.887×10^2; Milled 8.114×10^2 (highest efficacy)	All comparisons $P = 0.000$ (highly significant differences)	Not directly measured; literature suggests polishing affects roughness and microbial adhesion; milled resins have better surface finish and lowest microbial adhesion	Not reported; *in vitro* study without patient involvement
Alfahdawi, 2025[11]	G4 (Non-abrasive cleanser)	G3 (Chemical cleaner, sodium hypochlorite 0.5%)	Moderate zone of inhibition against *Candida albicans* (zone size ~11–15 mm for 3–5% TiO2) [CFU reduction inferred indirectly from zone of inhibition values as quantitative CFU counts were not provided; zones ranged 9–16 mm indicating antimicrobial efficacy]	Moderate zone of inhibition; G3 showed slight reduction in antibacterial activity	$P < 0.001$ (ANOVA for all outcomes)	Sodium hypochlorite (G3) caused the highest color change (ΔE > 3.7), significant surface roughness increase (Ra up to 0.43 µm), and moderate microhardness reduction. Non-abrasive cleanser caused minimal color and roughness changes. TiO2 nanoparticle reinforcement improved resistance to degradation and maintained hardness	No direct patient compliance data (*in vitro* study); chemical cleaners potentially cause material degradation; non-abrasive recommended for long-term use
Lim *et al*., 2025[29]	Ultrasonic cleaning (mechanical) alone not tested independently; test arm combined ultrasonic + chemical cleanser	Enzymatic peroxide-based denture cleanser (Polident 3 min™) used in both arms	No CFU counts provided; microbial richness (Chao 1 index) showed no significant difference between arms ($P = 0.343$)	Same as non-chemical, since chemical cleanser used in both arms	Beta diversity (Jaccard distance) analysis showed significant difference in microbial community structure ($P = 0.034$), indicating microbial community shift due to ultrasonic cleaning	Not directly assessed in this study; previous studies suggest minimal effect on denture surface with similar cleansers and ultrasonics	Compliance monitored by logbook and tablet count; no adverse effects reported

ANOVA, analysis of variance; ATCC, American Type Culture Collection; CAD, computer-aided design; CAM, computer-aided manufacturing; CFU, colony-forming unit; CHG, chlorhexidine gluconate; CI, confidence interval; CLSM, confocal laser scanning microscopy; CPC, cetylpyridinium chloride; CPC-Mont, cetylpyridinium chloride–montmorillonite; ISO, International Organization for Standardization; JIS, Japanese Industrial Standards; MTT, tetrazolium metabolic activity assay; PBS, phosphate-buffered saline; PCR, polymerase chain reaction; PMMA, polymethyl methacrylate; qPCR, quantitative polymerase chain reaction; Ra, arithmetic mean surface roughness; RCT, randomized controlled trial; SDA, Sabouraud dextrose agar; SEM, scanning electron microscopy; VHN, Vickers hardness number; ΔE, color difference metric.

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Table 3. Immersion duration of denture cleansers in the included studies and correspondence with real-world overnight soaking practices

Author/Year	Cleanser type	Immersion duration per session	Real-world relevance (≥6–8 h = overnight simulation)
Kumar *et al*., 2012[12]	Chemical/Household	8 h	Yes
Machado *et al*., 2012[23]	Chemical/Physical	10 min (CHX); 6 min (microwave)	No
Duyck *et al*., 2016[18]	Chemical & Mechanical	~8 h (overnight)	Yes
Badaró *et al*., 2017[24]	Chemical/Herbal	Not specified (rinsed after use)	No
Porwal *et al*., 2017[9]	Chemical	10 min	No
Mojarad *et al*., 2017[6]	Chemical/Physical	3–15 min	No
Sushma *et al*., 2017[15]	Herbal/Chemical	Surface scrub only (no immersion)	No
Han *et al*., 2020[3]	Chemical	Not specified (daily change)	No
Pandey *et al*., 2021[25]	Chemical	20 min	No
Asahara *et al*., 2022[26]	Non-chemical (CPC-Mont)	Continuous (7–28 days)	Yes (prolonged contact)
Nishi *et al*., 2022[5]	Various	~8 h (overnight)	Yes
Rajendran *et al*., 2022[7]	Tablet/Soap	10 min	No
Alfouzan *et al*., 2023[14]	Chemical	5–20 min	No
Takhtdar *et al*., 2023[10]	Chemical	3 min × 30 cycles	No
Wibawaningtyas *et al*., 2017[27]	Herbal	Continuous (12 days)	Yes (continuous exposure)
Varsha *et al*., 2023[28]	Chemical/Herbal	8 h	Yes
Lee *et al*., 2024[16]	Herbal	Daily immersion (duration not stated)	Unclear
Echhpal *et al*., 2024[2]	Chemical	~5–10 min (assumed)	No
Alfahdawi, 2025[11]	Chemical/Non-abrasive	Daily, brief	No
Lim *et al*., 2025[29]	Chemical & Ultrasonic	15 min	No

CHX, chlorhexidine.

denture cleansers.

Figure 5 illustrates the risk of bias assessment for the included *in vitro* studies using the modified SYRCLE Risk of Bias (RoB) tool,[22] which evaluates ten methodological domains (Items 1–10). Each domain was rated as low risk (++), unclear risk (+), or high risk (−). Most studies demonstrated a low risk across Items 1–5, covering sequence generation, baseline characteristics, allocation concealment, random housing, and participant blinding, indicating adequate internal validity. However, Items 6 and 7, assessing random outcome assessment and blinding of the outcome assessor, were frequently rated as high risk (−) or unclear (+), suggesting methodological weaknesses that may have introduced detection bias. Similarly, Items 8–10, which addressed blinding of assessors, incomplete outcome data, and selective reporting, also showed mixed ratings. A few studies showed consistently high methodological quality with low risk in nearly all domains, whereas others displayed variability, especially in areas involving blinding and reporting transparency. These findings point to inconsistent implementation of blinding protocols and inadequate reporting in several studies. Although the overall risk of bias was low in most cases, standardization in design and improved reporting of *in vitro* studies are needed to strengthen reproducibility and enhance the reliability of laboratory-based evidence on denture cleanser efficacy.

Table 4. Quality assessment for RCTs (Newcastle–Ottawa Scale)[20]

Author, Year	Selection (★/5)	Comparability (★/2)	Outcome/Exposure (★/3)	Total score (★/10)	Quality rating
Duyck *et al*., 2016[18]	★★★	★★	★★	★★★★★★★	Moderate
Badaró *et al*., 2017[24]	★★★	★★	★★	★★★★★★★	Moderate
Sushma *et al*., 2017[15]	★★★★	★★	★★★	★★★★★★★★★	High
Pandey *et al*., 2021[25]	★★★	★★	★★	★★★★★★★	Moderate
Nishi *et al*., 2022[5]	★★★★	★★	★★★	★★★★★★★★★	High
Rajendran *et al*., 2022[7]	★★★★	★★	★★★	★★★★★★★★★	High
Lim *et al*., 2025[29]	★★★★★	★	★★★	★★★★★★★★★★	High

RCTs, randomized controlled trials.

Table 5. Quality assessment for *in vitro* studies using the QUIN tool[21]

S. No	Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Total score	Final score	Risk of bias
1	Kumar *et al*., 2012[12]	1	1	1	2	2	1	1	1	1	1	1	2	15	62.5	Medium
2	Machado *et al*., 2012[23]	2	1	2	2	1	2	1	2	1	1	2	1	18	75	Low
3	Porwal *et al*., 2017[9]	1	1	1	1	2	1	1	1	1	2	1	2	15	62.5	Medium
4	Mojarad *et al*., 2017[6]	2	1	2	2	1	2	1	2	1	2	2	1	19	79.17	Low
5	Han *et al*., 2020[3]	1	1	2	1	2	1	2	1	1	1	1	2	16	66.67	Medium
6	Asahara *et al*., 2022[26]	2	1	2	2	1	2	1	2	1	1	2	1	18	75	Low
7	Alfouzan *et al*., 2023[14]	2	2	2	1	2	2	1	2	2	2	1	2	21	87.5	Low
8	Takhtdar *et al*., 2023[10]	2	2	2	1	2	2	2	2	2	2	1	1	21	87.5	Low
9	Wibawaningtyas *et al*., 2017[27]	1	1	1	1	2	1	1	1	1	1	2	2	15	62.5	Medium
10	Varsha *et al*., 2023[28]	2	2	2	2	2	1	2	2	2	2	2	2	23	95.83	Low
11	Lee *et al*., 2024[16]	2	2	2	2	2	2	2	1	2	2	2	2	23	95.83	Low
12	Echhpal *et al*., 2024[2]	2	2	2	1	2	2	2	2	2	2	1	2	22	91.67	Low
13	Alfahdawi, 2025[11]	2	2	2	2	2	2	1	2	2	2	2	2	23	95.83	Low

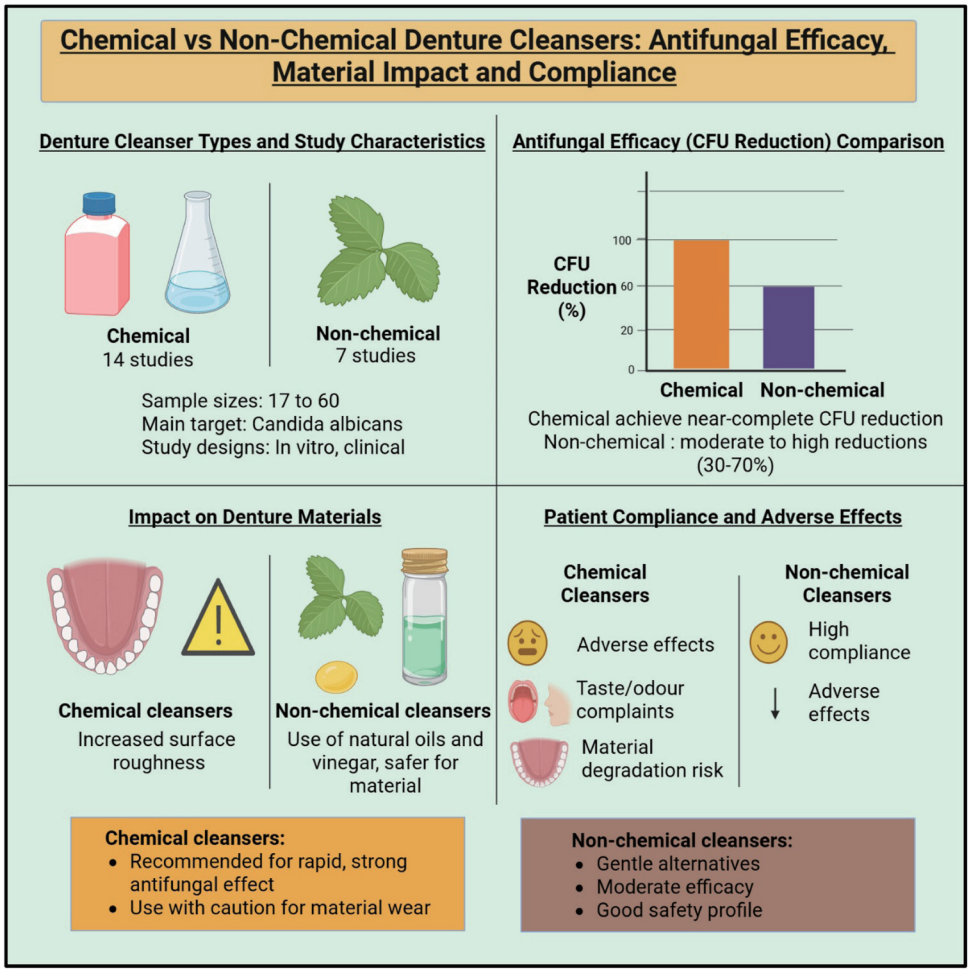

Fig. 2. Antifungal activity and material effects of chemical and non-chemical denture cleansers [Comparison between chemical and non-chemical denture cleansers in terms of *Candida* reduction and material effects]. Chemical cleansers provide stronger antimicrobial action but can damage surfaces. Herbal agents, ultrasonication, and microwave methods provide moderate action while maintaining denture material stability. CFU, colony-forming unit.

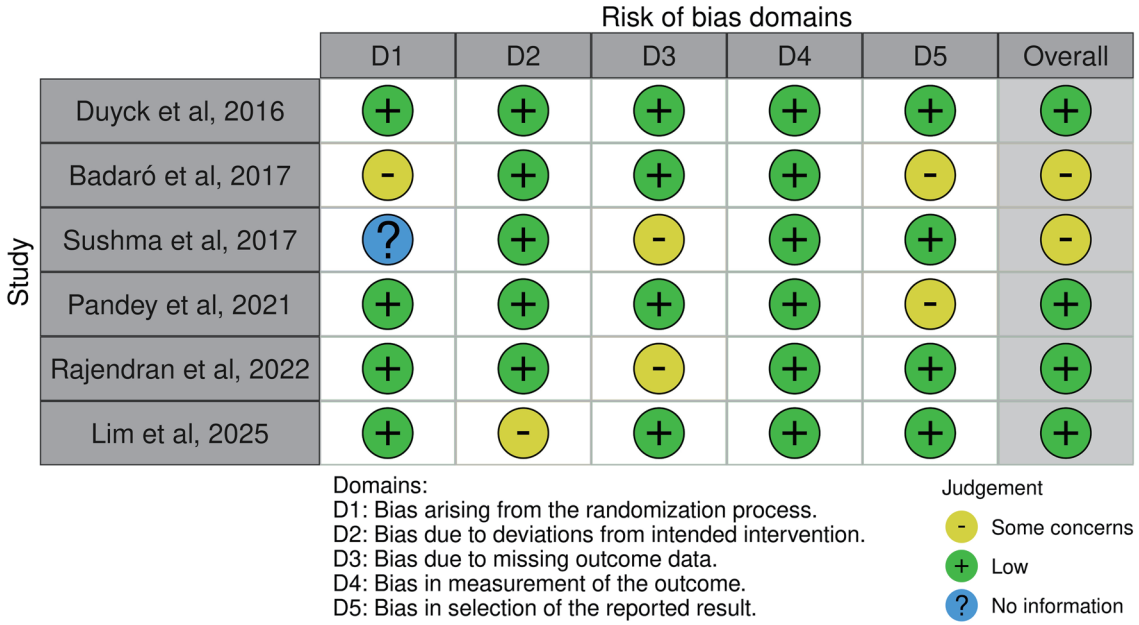

Fig. 3. Risk of bias assessment for randomized controlled trial (RCT) studies using the ROB2 tool (individual studies).[19]

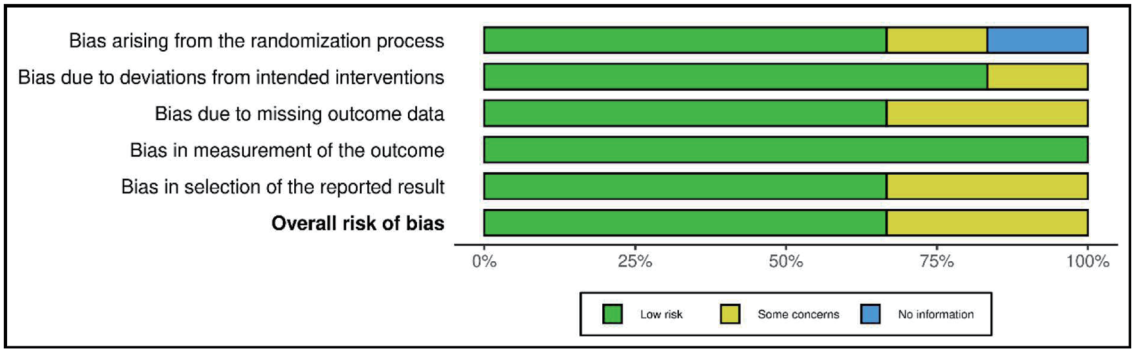

Fig. 4. Risk of bias assessment for randomized controlled trial (RCT) studies using the ROB2 tool (overall bias).[19]

Author (year)	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10
Kumar et al, 2012	++	+	++	++	++	-	++	+	++	-
Machado et al, 2012	++	++	++	+	++	++	++	-	++	+
Porwal et al, 2017	+	++	++	+	++	++	++	-	++	+
Mojarad et al, 2017	++	+	++	++	++	-	++	+	+	++
Han et al, 2020	++	++	++	++	-	++	++	++	++	++
Asahara et al, 2022	++	++	+	++	+	++	++	++	-	++
Alfouzan et al, 2023	+	++	++	++	++	++	-	++	++	++
Takhtdar et al, 2023	++	+	++	++	++	-	++	+	++	++
Wibawaningtyas et al, 2017	++	++	++	++	++	++	-	++	++	++
Varsha et al, 2023	+	++	++	+	++	++	++	-	++	+
Lee et al, 2024	++	+	++	++	++	-	++	+	-	++
Echhpal et al, 2024	++	++	+	++	++	++	++	++	++	++
Alfahdawi, 2025	++	++	++	+	++	++	++	-	++	+

Fig. 5. Risk of bias assessment for *in vitro* studies using the modified SYRCLE RoB tool.[22]

Discussion

Effective denture hygiene is critical for preventing *Candida* species colonization and denture-induced stomatitis. In this systematic review, we compared the antifungal efficacy of chemical and non-chemical denture cleansers used on RDPs. RCTs and *in vitro* studies that assessed the reduction in *Candida* CFUs were included in this review. This study evaluated quality using various tools to ensure methodological rigor. By synthesizing the available evidence, we aimed to identify the most effective cleansing strategies that preserve the structural integrity of prosthetic materials while effectively reducing microbial biofilms, particularly *Candida* spp.

The present systematic review confirms that both chemical and non-chemical denture cleansers reduce *Candida* spp., but chemical agents such as sodium hypochlorite, enzymatic peroxide tablets, and chlorhexidine consistently provide superior antifungal activity.[24,30–32] These agents effectively disrupt mature biofilms and significantly reduce fungal viability. Multiple *in vitro* and clinical studies have supported these outcomes, demonstrating marked CFU reduction and surface decontamination on conventional PMMA and digitally fabricated computer-aided design/computer-aided manufacturing (CAD/CAM) denture bases.[23,25] Studies have highlighted the strong antifungal effect of sodium hypochlorite, even at low concentrations and with short immersion durations.[30,33,34] In contrast, non-chemical cleansers such as Triphala, neem, clove oil, *Cnidium officinale*, aloe vera, and marine algae showed moderate efficacy with greater variability in outcomes.[35–39] Other studies have demonstrated that these agents could lower *Candida* counts effectively, although longer exposure or daily use was often necessary.[16,28,35] Emerging approaches such as ozonated water,[37] ultraviolet disinfection,[40] and eugenol-based solutions have also gained interest for their potential as safe adjunctive therapies.[36] However, evidence has suggested that these non-chemical agents are currently less effective than traditional chemical cleansers and are best used as supplementary measures rather than stand-alone treatments.[41–45]

Several studies have reported that chemical cleansers, despite their antifungal effectiveness, may negatively affect denture material properties, such as color stability, surface roughness, and hardness.[9–11] Increased surface roughness and degradation were noted after repeated exposure to sodium hypochlorite and peroxide-based solutions.[9,14] Other findings showed that regular chemical disinfection can compromise the surface finish and mechanical strength of PMMA resins, making them more prone to wear and deterioration over time.[30,33] More recent investigations confirmed that extended chemical use reduces resin hardness and promotes surface porosity, which could increase the risk of microbial recolonization.[34,46] In contrast, non-chemical agents such as neem, *Cnidium officinale*, and ozonated water produced minimal alterations in surface texture or structure, preserving the integrity of denture materials over multiple uses.[37,38,43] These outcomes suggest that material compatibility remains a key consideration in selecting denture cleansers. Plant-based and non-thermal disinfectants help maintain denture color and surface texture.[16,26] Patient compliance significantly influences hygiene outcomes, as strong chemical odors or metallic tastes from some agents discourage regular use. In contrast, herbal and ozone-based cleansers were better tolerated owing to their mild flavor and natural appeal.[36–38] Patient feedback and *in vivo* data supported these preferences. These results highlight the usefulness of non-chemical options, especially for individuals with sensitive oral tissues or concerns regarding aesthetics and long-term material integrity.

This systematic review synthesizes findings from both RCTs and *in vitro* studies, highlighting the clinical and laboratory effectiveness of chemical and non-chemical denture cleansers. Several RCTs have confirmed the antifungal efficacy of both chemical and non-chemical denture cleansers. One study demonstrated that combining ultrasonic cleaning with sodium hypochlorite led to significantly improved *Candida* reduction on denture surfaces.[29] Another trial showed that although all tested methods reduced *C. albicans* colonies, chemical agents produced more consistent results.[7] A herbal denture cleanser also showed antifungal potential, though further long-term evaluations are advised.[15] Sodium hypochlorite and *Ricinus communis* oil both significantly helped lower microbial loads.[31] Another study evaluated different cleaning approaches for flexible dentures and confirmed the effectiveness of both mouthwash and denture cleansers in biofilm removal.[34] These results suggest that while chemical cleansers offer consistent antimicrobial effects, selected non-chemical methods also yield promising outcomes, especially when used adjunctively or in combination with physical cleaning techniques.[24,29,31,34] The ROB2 tool indicated low-to-moderate risk of bias in most RCTs, particularly in randomization and outcome assessment domains, as depicted in Figures 4 and 5. However, a few studies lacked clarity in terms of protocol adherence or blinding methods. *In vitro* studies assessed using QUIN and modified SYRCLE RoB tools consistently supported clinical findings, demonstrating that both chemical and non-chemical denture cleansers can significantly reduce *Candida* biofilms while maintaining material compatibility. High-quality experimental evidence has demonstrated strong antifungal efficacy and favorable surface interactions for various agents, including natural extracts and ozonated water. These alternative approaches demonstrated comparable antimicrobial potential to conventional chemical cleansers, emphasizing the importance of evidence-based selection tailored to material sensitivity and clinical needs.[11,16,28,30]

The findings of this systematic review partially align with those of earlier studies, particularly in confirming the superior antifungal efficacy of chemical denture cleansers. Prior reviews identified hypochlorite-based cleansers as the most effective against *Candida* biofilms,[8] a result echoed in the current analysis. Citric acid-based solutions were effective in reducing *C. albicans* recolonization.[41] Hybrid cleansing strategies, such as combining ultrasonic devices with enzymatic tablets, were found to enhance biofilm removal.[29] Newer formulations, including eugenol-based tablets and phytotherapeutic agents such as Triphala, neem, and aloe vera,[35,36] demonstrated moderate antifungal activity and were particularly suitable for patients sensitive to chemical agents. Non-contact methods, such as ozonated water and UV disinfection,[37,40] also offer effective alternatives with minimal surface degradation. Bio-friendly agents such as cinnamaldehyde,[43] *Cnidium officinale*,[16] and *Turbinaria conoides* have emerged as promising options,[28] showing both antimicrobial efficacy and compatibility with denture surfaces. Comparative studies have further confirmed that commercial and experimental cleansers differ in efficacy and material impact, underscoring the need to select products that balance antifungal potency with surface preservation.[4,42,47]

Prolonged use of denture cleansers requires attention to sustainability, material compatibility, and appropriate outcomes. Chemical agents such as sodium hypochlorite and peroxides can suppress *Candida* spp.; however, repeated exposure can increase surface roughness and produce discoloration, thus supporting recolonization at later stages.[9,10,46] Phytotherapeutic options such as *Cnidium officinale*,[16] *Turbinaria conoides*,[28] and *Ricinus communis* have

shown moderate antifungal effects with minimal material damage and are suitable for elderly patients and those with reduced immunity.[24] Studies have highlighted bioactive analogues such as oxadiazoles, gallates, and pyridine derivatives, which can act on *Candida* virulence factors such as Als3 and Sap2.[16,36] The combination of ultrasonication with low-concentration enzymatic or plant-based cleansers improves biofilm removal and reduces chemical load.[29] Nano-encapsulation and antimicrobial agents can improve biofilm penetration and maintain constant release during denture cleaning. Ultrasonication with low-dose herbal extracts, nano-encapsulated eugenol or cinnamaldehyde in controlled-release carriers, and denture resins infused with TiO_2 or zinc dimethacrylate are commonly used methods. Thus, these designs facilitate the reduction of *Candida* load while restricting surface damage and providing appropriate hygiene.

Strengths and limitations

This systematic review has several key strengths. It adhered to PRISMA 2020 guidelines and included a broad spectrum of study designs, RCTs, non-randomized clinical trials, and *in vitro* studies, allowing for a well-rounded comparison of denture cleanser efficacy. The use of multiple validated risk-of-bias tools improved methodological accuracy. The inclusion of recent studies up to 2025, covering novel agents such as ozonated water and eugenol-based cleansers, added current clinical value. This review also considered material effects and patient compliance, making it relevant to daily prosthodontic practice. However, this review has some limitations. Heterogeneity in study protocols prevented meta-analysis. Incomplete reporting of blinding and randomization in some trials may reduce validity. Non-English studies and gray literature were not included, which may have led to the omission of relevant data.

Future directions

Future research should focus on standardized long term clinical trials that directly compare chemical and non-chemical denture cleansers using uniform protocols for concentration, immersion time, and outcome assessment. Studies should also examine new bioactive agents, plant derived compounds, nano encapsulated antifungals, and antimicrobial denture materials with respect to efficacy, safety, and effects on denture durability. Patient focused outcomes, compliance, taste acceptability, mucosal tolerance, and cost effectiveness also require systematic evaluation to support individualized denture hygiene guidance.

Conclusions

This systematic review shows that both chemical and non-chemical denture cleansers effectively reduce *Candida species*, with chemical agents demonstrating more consistent antifungal action. However, material compatibility, patient tolerance, and safety remain important factors in cleanser selection. The findings support the use of adjunctive or alternative non-chemical agents, such as herbal and ozone-based cleansers, particularly for long-term use or in sensitive individuals. Clinicians should balance microbial efficacy with the preservation of denture integrity and patient compliance. Future research should focus on standardized protocols, long-term clinical outcomes, and patient-reported measures. This review contributes to the scientific literature by integrating current evidence, evaluating emerging cleansers, and guiding clinical decisions for maintaining denture hygiene and preventing prosthesis-related fungal infections.

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Conflict of interest

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Author contributions

Study conception and design, data acquisition, data analysis, data interpretation, drafting of the manuscript, critically revised the manuscript for important intellectual content (MWN, AZA, BAA, MAA, MHA, AMG, MHA, MS). All authors have approved the final version and publication of the manuscript.

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