

Hygiene practices in removable prosthodontics: A systematic review

S Papadiochou  | G Polyzois

Department of Prosthodontics, School of Dentistry, Faculty of Health Sciences, National and Kapodistrian University of Athens, Athens, Greece

Correspondence

Sofia Papadiochou, School of Dentistry, Department of Prosthodontics, National and Kapodistrian University of Athens, Greece.
Email: sofia Papadiochou@gmail.com

Abstract

Objective: To systematically review the recent scientific evidence about the hygiene practices of removable prostheses relative to the effectiveness, colour and dimensional stability. This review aimed also to identify patients' attitudes and habits towards denture hygiene.

Methods: Three electronic databases (MEDLINE/PubMed, Scopus and Cochrane Library) were screened, in English language, between January 1995 and December 2016. A supplementary hand search in the reference list of the identified articles was also performed. Controlled clinical trials (CCTs) involving patients with no clinical signs of denture stomatitis along with a comprehensive aim to assess the effectiveness of hygiene interventions and their impact on prosthesis colour and dimensional stability were eligible for inclusion.

Results: Following a thorough screening of titles/abstracts/full texts and consideration of the defined inclusion criteria, 21 CCTs examined the effectiveness of the hygiene approaches, 3 evaluated the colour stability of dentures subjected to hygiene practices, 2 examined the dimensional stability of dentures following microwave disinfection and 30 studies registered patients' attitudes and habits towards denture hygiene.

Conclusions: Combined application of different hygiene interventions, including brushing or ultrasound vibration in conjunction with chemical agents, leads to more effective outcomes (reduction in denture biofilm percentage and/or number of microorganisms' colony-forming units). The dimensional stability seems to be unaltered, but the number of clinical trials was limited. Critical concentrations of cleansing solutions along with the duration of their implementation influence the serviceability of dentures regarding colour stability. Brushing represents the most commonly applied hygiene practice, while denture wearers' attitudes are not complied with the recommended guidelines considering the reported frequency of hygiene practices and the continuous denture wear.

KEYWORDS

biofilm, colour stability, dimensional stability, disinfection, habits, hygiene, removable prosthodontics

1 | INTRODUCTION

The issue of removable prostheses hygiene is considered of utmost importance as the available scientific evidence suggests the development of both oral and systemic infections, as a result of improper hygiene habits among removable denture wearers.¹⁻³ Denture base acrylic resin is easily colonized by *Candida* spp. and bacteria of both intra- and extra-oral origin as well, leading to denture stomatitis, while potential respiratory pathogens have also been detected on denture surfaces.⁴⁻⁶ Based on the findings of a recent systematic review, both disinfection and antiseptic methods were equivalently effective with antifungal therapy in the treatment for denture stomatitis.^{7,8} The study highlighted the issue of oral hygiene education, which is considered crucial factor in promoting removable denture wearers' compliance with evidence-based oral hygiene guidelines.^{7,9}

The major target of all the hygiene interventions in the field of Removable Prosthodontics is to eliminate pathogenic microorganisms' counts preventing the reestablishment of a pathogenic biofilm, as well. Denture biofilm removal can be achieved via the application of different types of hygiene practices including mechanical methods, chemical agents and irradiation or combination of the aforementioned methods.¹⁰⁻³⁰ Brushing represents the most commonly applied mechanical method combining the advantage of simplicity, effectiveness and low cost.³¹⁻⁵⁵ Chemical cleansing methods can include a wide range of treatments: hypochlorites, peroxides, enzymes, acids, crude drugs and mouthwashes.⁵⁶ Ultrasonic devices pair the mechanical removal of biofilm with the concurrent use of a chemical agent.⁵⁷ Irradiation of dentures through photodynamic therapy (PDT) or microwave application has also been described as an alternative disinfection method of complete dentures.^{21,22} An ideal denture hygiene method should, in addition to bactericidal and fungicidal action, possess the ability to remain unaltered the physical and mechanical properties of both denture base and prosthetic teeth.¹⁴ In particular, colour and dimensional stability of a denture material are considered prerequisites for its clinical longevity.⁵⁸⁻⁶¹

A systematic review of the current hygiene interventions in Removable Prosthodontics is required to inform oral healthcare providers about the effectiveness of the available hygiene measures in terms of denture biofilm reduction and/or elimination of microorganisms' counts, as well as to investigate the effect of hygiene practices on removable prosthesis colour and dimensional stability under clinical conditions. Finally, this article aimed to document current patients' attitudes and habits towards removable dentures hygiene.

2 | MATERIALS AND METHODS

The conduct of this systematic review relied on Preferred Reporting Items for Systematic Reviews Meta-Analyses (PRISMA Statement) and PICO(S) approach (Patient or Population, Intervention, Control or Comparison, Outcome and Study types).⁶² Four questions were generated through PICO (S) approach in order to review systematically

the available literature. To identify all the potentially relevant to the scopes of this review articles, a specific list of keywords and phrase searches was formulated. An electronic systematic review of English-language dental literature on MEDLINE/PubMed, Scopus and Cochrane Library databases was conducted from January 1995 up to December 2016 (Table 1).

Only controlled clinical trials (CCTs) meeting specific inclusion criteria were appropriate for full-text reading (Table 1). Pertaining to the study population, removable denture wearers with no clinical signs of denture stomatitis and scheduled to follow a specific hygiene practice/protocol for their prostheses were included. There was no limitation towards the sex or age of the study population. To address the first PICO question, only CCTs comparing the effectiveness of different hygiene approaches were eligible for inclusion. In answer to the rest of PICO questions, CCTs investigating the impact of the hygiene intervention on denture sanitation, colour and dimensional stability before and after the exposure of removable dentures in a specific hygiene protocol were considered potentially relevant. To specify the outcome parameters of the current review, meticulous consideration of both available reviews and intervention outcomes of the included studies was performed (Table 1).

The eligibility of the potentially relevant articles was verified by both authors (S.P. and G.P.) who independently screened at first the titles and the abstracts evaluating the appropriateness of articles for full-text reading. When disagreement emerged, titles were included to obtain full texts and consensus was achieved after discussion. Finally, a further manual search in the reference list of the selected full-text articles was conducted and articles not yet included were also added.

Within each included study, among the data items that were recorded were the (i) author names, (ii) date of publication, (iii) type of study, (iv) control group, (v) sample size and characteristics, (vi) type of hygiene intervention, (vii) producer's name and/or commercially available hygiene agent brand name, (viii) applied method for the evaluation of effectiveness of hygiene intervention, (ix) applied method for the assessment of colour stability, (x) applied method for dimensional stability and (xi) results.

It was not among the scopes of this systematic review to perform a statistical comparison of results and eventually a meta-analysis taking into account the diversity in the study design (duration of the follow-up period, sequence of different applied hygiene practices, multiple hygiene agents, heterogeneity among the study populations) as well as the implementation of different techniques for the assessment of the effectiveness of hygiene practices qualitatively (measurement of biofilm percentage area) and/or quantitatively (quantity/number of colony-forming counts of microorganisms).

The authors evaluated the risk of bias via the Cochrane Collaboration Tool for the randomized controlled trials (RCTs) and MINORS index for N-RCTs.^{63,64} The degree of bias was classified as low risk if all the criteria existed, moderate risk when only 1 criterion was absent and high risk in the case of 2 or more missing criteria. Comparative studies with MINORS scores of (i) 24 were rated as low risk of bias, (ii) 20-24 as moderate risk and (iii) <20 as high risk.

Finally, the authors (S.P and G.P) appraised the quality of the existing evidence and the strength and direction of the recommendations as well, via the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system.⁶⁵ The following GRADE criteria were assessed: risk of bias, consistency of results, directness of evidence, precision of data, publication bias and direction of recommendations. In the event of any disagreements between the authors, these were resolved after further discussion.

3 | RESULTS

3.1 | Literature search and selection results

The electronic search in the MEDLINE/PubMed, Scopus and Cochrane Library databases provided a total of 780 abstracts that were considered potentially relevant. In the second phase of search strategy, following a detailed screening of the titles and abstracts of the manuscripts, 77 articles received full-text reading. Of 47 clinical trials, 22

TABLE 1 Systematic search strategy

Focus questions	<ol style="list-style-type: none"> 1. In patients wearing removable dentures (P), the effectiveness (O) (reduction in denture biofilm AND/OR number of colony-forming units of microorganisms) depends on the type (C) of the applied hygiene practice (I)? 2. In patients wearing removable dentures (P), what is the effect of the applied hygiene practice (I) on denture sanitation (O)? 3. In patients wearing removable dentures (P), what is the effect of the hygiene practice (I) on prosthesis colour stability (O)? 4. In patients wearing removable dentures (P), what is the effect of the hygiene practice (I) on prosthesis dimensional stability (O)?
Search strategy	
Population	<ul style="list-style-type: none"> • Patients wearing complete dentures, removable partial dentures, or tooth- and implant-supported overdentures, either new or replacement or relined
Intervention or exposure	
Comparison	<p>Removable dentures (control groups)</p> <ul style="list-style-type: none"> • before the implementation of a specific hygiene approach or protocol (baseline) or • subjected only to brushing or • immersed in distilled water or saline
Outcome	<p>Effectiveness/sanitation</p> <ul style="list-style-type: none"> • reduction in denture biofilm percentage area and/or • elimination of the quantity/number of colony-forming counts of microorganisms (killing or inactivation) <p>Colour stability Dimensional stability</p>
Search terms	<p>#"complete dentures," "disinfection," "disinfecting agents," "disinfectants," "complete dentures" AND "cleansers," "cleansing," "cleansing agents," "biofilm removal," "removable partial dentures," "overdentures," "overdentures," "habits," "hygiene," "trends," "color stability," "dimensional stability," "dimensional changes"#</p>
Database search	MEDLINE/PubMed, Scopus, Cochrane Library
Electronic database searched	
Selection inclusion criteria	<p>English language Clinical studies of at least 10 treated patients with no clinical signs of denture stomatitis Prospective: randomized controlled trials (RCT), non-randomized controlled trials (N-RCT) Retrospective: controlled, case control Description of the applied disinfection method Producer's name and/or commercially available hygiene agent brand name</p>
Selection exclusion criteria	<p>Non-English language Unrelated to the topic articles Reviews In vitro studies Ex vivo studies Pilot studies Case reports Case series (<10 patients) Animal studies Studies with</p> <ul style="list-style-type: none"> • patients with clinical evidence of denture stomatitis • no report of producer's name and/or commercially available hygiene agent brand name • no control group

were excluded for the reasons reported in Table 2. Eventually, 25 CCTs met the predefined inclusion criteria in order to arrive at the final selection.^{10-30,58-61} These were further classified into 4 categories

according to their objective of investigation; 21 CCTs (17 RCTs and 4 N-RCTs) examined denture hygiene practices in terms of effectiveness pertaining to either killing or inactivation of microorganisms or

TABLE 2 Excluded clinical trials

Study	Title	Reason for exclusion
André et al, (2011)	Prevalence of mutans streptococci isolated from complete dentures and their susceptibility to mouthrinses	An experimental denture cleaning paste
Andrucioi et al, (2004)	Comparison of 2 cleansing pastes for the removal of biofilm from dentures and palatal lesions in patients with atrophic chronic candidiasis	Patients with atrophic chronic candidiasis
Aoun et al, (2015)	Effectiveness of hexetidine 0.1% compared to chlorhexidine digluconate 0.12% in eliminating <i>Candida albicans</i> colonizing dentures: a randomized clinical in vivo study	Patients with clinical signs of Newton's type II denture stomatitis
Aoun et al(2015)	Effectiveness of hexetidine 0.1% compared to chlorhexidine digluconate 0.12% in eliminating <i>Candida albicans</i> colonizing dentures: a randomized clinical in vivo study	Patients with clinical signs of Newton's type II denture stomatitis
Banting and Hill, (2001)	Microwave disinfection of dentures for the treatment of oral candidiasis	Patients with positive test for <i>C. albicans</i> pseudohyphae
Barnabe et al, (2002)	Effects of disinfection agents on the reduction of <i>streptococcus mutans</i> and yeast in complete dentures users	Patients with denture stomatitis according to Newton classification
Barnabé et al, (2004)	Efficacy of sodium hypochlorite and coconut soap used as disinfecting agents in the reduction of denture stomatitis, <i>Streptococcus mutans</i> and <i>Candida albicans</i>	Patients with clinical lesions characteristic of prosthetic stomatitis prior to treatment
Cross et al, (1998)	A comparison of fluconazole and itraconazole in the management of denture stomatitis: a pilot study	Patients with denture stomatitis
de Oliveira et al, (2011)	Effect of a denture cleanser on the concentration of volatile sulphur compounds and denture biofilm in institutionalised elderly	No report of the commercially available brand of the hygiene practice
Glass et al, (2011)	Evaluation of cleansing methods for previously worn prostheses.	Ex vivo
Jose et al, (2010)	Reducing the incidence of denture stomatitis: are denture cleansers sufficient	Patients with denture stomatitis
Koray et al, (2005)	Fluconazole and/or hexetidine for management of oral candidiasis associated with denture-induced stomatitis	Patients with denture stomatitis
Kulak et al, (1997)	Scanning electron microscopic examination of different cleaners: surface contaminant removal from dentures	<10 included patients
Gornitsky M et al, (2002)	A clinical and microbiological evaluation of denture cleansers for geriatric patients in long-term care institutions	Patients with denture stomatitis
Mähönen et al, (1998)	The effect of prosthesis disinfection on salivary microbial levels	Patients with inflammatory soft tissues
Neppelenbroek et al, (2008)	Effectiveness of microwave disinfection of complete dentures on the treatment of <i>Candida</i> -related denture stomatitis	Patients showing palatal inflammation
Sanita et al, (2012)	Microwave denture disinfection vs nystatin in treating patients with well-controlled type 2 diabetes and denture stomatitis: a randomized clinical trial	Patients with denture stomatitis
Segundo Ade et al, (2014)	Clinical trial of an experimental cleaning solution: antibiofilm effect and integrity of a silicone-based denture liner	No commercially available hygiene agent
Sesma et al, (2013)	Effectiveness of denture cleanser associated with microwave disinfection and brushing of complete dentures: in vivo study	Patients with clinical signs of Newton's type II denture stomatitis
Silva et al, (2012)	Comparison of denture microwave disinfection and conventional antifungal therapy in the treatment of denture stomatitis: a randomized clinical study	Denture wearers with denture stomatitis
Uludamar et al, (2010)	In vivo efficacy of alkaline peroxide tablets and mouthwashes on <i>Candida albicans</i> in patients with denture stomatitis	Denture wearers with clinical evidence of denture stomatitis
Webb et al, (2005)	A 2-y study of <i>Candida</i> -associated denture stomatitis treatment in aged care subjects	Patients with denture stomatitis

removal of denture biofilm in individuals with no clinical signs of denture stomatitis,¹⁰⁻³⁰ 3 CCTs examined denture hygiene approaches in terms of colour stability^{14,60,61} and 2 CCTs tested microwave disinfection with regard to dimensional stability.^{58,59} Finally, 30 articles investigated the attitudes and habits of removable denture wearers towards the hygiene of their prostheses,^{31-55,66-70} including the frequency,^{31,34-39,42,44-54,69} the type^{31-55,66,70} of the applied hygiene interventions as well as the presence of nocturnal wearing of removable dentures.^{33-37,39,40,45,46,50,67,68}

3.2 | Study design

The effectiveness of the hygiene approach was examined via the calculation of the quantity of microorganisms through conventional microbiological analysis,^{12,14-18,21,22,24,27,30} through evaluation of the area percentage covered with denture biofilm^{10,11,13,20,23,25} or their combination.^{19,26,28,29} With respect to the design of the clinical studies investigating the quantity of microorganisms through microbiological analysis, 2 CCTs performed identification of periodontal pathogens and *Candida albicans*,^{15,29} 2 CCTs both *Candida* spp. and *Mutans streptococci*,^{12,24} 2 CCTs exclusively *Candida* spp.,^{16,26} 1 CCT *Streptococcus* spp., *Candida* spp., *Neisseria* spp.,¹⁸ 2 CCTs *Streptococcus* spp., *Candida* spp and *Staphylococcus*^{21,22} and 2 CCTs multiple microbial species including *Candida* spp.^{14,30}

With regard to the study population, of the 21 CCTs, 12 aimed to investigate the effectiveness of the hygiene approach in complete denture wearers,^{11-14,18-20,23,25-30} 5 studies in maxillary complete denture wearers,^{10,17,21,22,24} 2 studies in mandibular complete denture wearers^{15,16} and 1 study in relined complete denture wearers.¹⁰

3.2.1 | Type of hygiene intervention

From the 21 CCTs, 4 aimed to investigate exclusively the disinfection effect of chemical agents including effervescent tablets^{15,27,30} and/or solutions^{14,30} (alkaline peroxide, sodium perborate, potassium peroxymonosulphate, sodium bicarbonate and potassium monosulphate glutaraldehyde, sodium hypochlorite, chlorhexidine digluconate), 3 CCTs examined exclusively the effectiveness of brushing,^{19,23,28} 2 CCTs the effectiveness of irradiation methods involving PDT²¹ and microwave energy²² and 12 CCTs compared the effectiveness of mechanical methods, chemical agents and their combined application.^{10-13,16-18,20,24-26,29}

3.3 | Study outcome results

3.3.1 | Comparative studies

Of the 12 comparative studies, 4 RCTs investigated the efficacy of brushing, effervescent alkaline peroxide solutions and ultrasound vibration as well as their combined effect on denture sanitation^{11,12,18,29} and 8 comparative CCTs^{10,13,16,17,20,24-26} examined the disinfection effectiveness of brushing, immersion in soaking solutions and their combined effect.

3.3.2 | Ultrasound vibration with/without Brushing PLUS Chemical agents

All the available RCTs demonstrated that an effervescent tablet combined with mechanical cleaning^{12,18,29} was more effective for denture sanitation compared with mechanical cleaning alone (either brushing or ultrasound vibration) considering the significant reduction in total bacterial and *Mutans streptococci* counts (Table 2). In terms of *Candida* spp. counts, the results of existing evidence are conflicting; 2 RCTs reported no significant difference between the tested (brushing alone, brushing plus effervescent tablets with/without ultrasound cleaning) sanitation methods.^{12,29} Opposed to the latter, Nishi et al¹⁸ cited that ultrasound cleaning in conjunction with immersion in alkaline peroxide solution led to a significant reduction in *Candida* spp. counts (Table 3).

3.3.3 | Brushing PLUS Chemical agents

Considering the results arising from biofilm percentage area assessment^{13,26,27} and/or microbiological analysis^{16,17,24} (*C. albicans*/yeasts'/total microorganisms' counts), immersion in effervescent alkaline peroxide, *R. communis*, sodium lauryl sulphate (SLS) or 0.12%, 2.0% or 4% w/v chlorhexidine gluconate solutions yielded the best outcomes relative to sanitation when used as a supplementary hygiene method combined with brushing (Table 4).

3.3.4 | Brushing

Three CCTs that investigated exclusively the effectiveness of brushing advocated the significant reduction in the biofilm area percentage of the removable dentures.^{19,23,28} Additionally, brushing with dentifrice attained greater removal of biofilm area percentage compared with brushing with neutral pH gel soap.^{19,23} No noticeable difference was observed in yeast CFUs in removable dentures subjected to brushing with either specific denture dentifrice or neutral liquid or soap and artificial saliva.¹⁹ Additionally, yeast CFUs remained similar in dentures subjected to brushing with 3 different toothbrushes and dentifrice²⁸ (Table 5).

3.3.5 | Chemical agents

All the removable dentures after their immersion in chemical solutions (alkaline peroxide, 0.5% sodium hypochlorite, chlorhexidine digluconate)^{14,15,27,30} presented significantly lower levels of bacteria and *Candida* spp counts (Table 6). No statistically significant reduction in the mean values of colony-forming units (CFUs) was observed when oral rinse with 0.2% w/v chlorhexidine gluconate was implemented as adjunct to complete denture immersion in alkaline peroxide solution.²⁷

3.3.6 | Irradiation

Microwaving at 650 W for 3 minutes was an effective method for clinical sterilization of complete dentures.²² Besides, microwave irradiation of complete dentures at 650 W for 2 minutes resulted in a

TABLE 3 Comparative studies addressing first and second PICO questions; contrast between ultrasound cleaning AND effervescent tablets AND brushing AND their combined effect on denture sanitation

Authors (Year)	Type of Study	Control group	Tested hygiene practices	Number of patients	Outcome assessment	Results
de Andrade et al ¹² (2011)	RCT	Brushing with water (A)	Brushing AND effervescent tablets (B) (Corega Tabs, Block Drug Company, Inc., Jersey City, NJ, USA) Brushing AND ultrasonic device (C) (Ultrasonic Cleaner, model 2840 D) Brushing AND effervescent tablets AND ultrasonic vibration (D)	77 complete denture wearers	Microbiological analysis	<i>Candida</i> spp. counts; no statistically significant reduction between A method AND all tested methods ($P > .05$) <i>Mutans streptococci</i> counts; statistically significant reduction in B or D method ($P < .05$) Total aerobes counts; statistically significant reduction in B or D method ($P < .05$)
Cruz et al ¹¹ (2011)	RCT	Brushing with water (A)	Brushing AND effervescent tablets (B) (Corega Tabs Block Drug Company, Inc., USA) Brushing AND ultrasonic device (C) (Ultrasonic Cleaner, model 2840 D) Brushing AND effervescent tablets AND ultrasonic vibration (D)	80 complete denture wearers	Biofilm percentage	Biofilm percentage; statistically lower in B, C or D methods ($P < .001$), compared with A method
Duyck et al ²⁹ 2016	Cross-over RCT	Brushing AND immersion in water (A)	Brushing and immersion in water with effervescent tablet (B) (Corega antibacterial denture cleanser tablets, Stafford Miller, Ireland) Ultrasonic vibration AND immersion in water (C) Ultrasonic vibration AND immersion in water with effervescent tablet (D)	13 complete denture wearers	Microbiological analysis Biofilm percentage	Total bacterial counts; statistically significant reduction between A or C method AND B or D method ($P < .01$) Total bacterial counts; more significant reduction in D method ($P < .01$) <i>C. albicans</i> counts; no statistically significant reduction among the tested groups ($P > .05$) Biofilm percentage; no significant reduction among the tested groups ($P > .05$)
Nishi et al ¹⁸ (2014)	RCT	Brushing with water (A)	Effervescent tablets (B) (Polident GlaxoSmithKline Co. Ltd., Tokyo, Japan) Ultrasonic vibration with water (C) (BRANSONIC Ultrasonic Cleaner Model B3200; Branson Ultrasonic Co. Ltd) Brushing with water + effervescent tablets (D) Ultrasonic vibration + effervescent tablet (E)	50 complete denture wearers	Microbiological analysis	Total microorganisms counts; statistically significant reduction between B, D or E AND A or C methods <i>Candida</i> spp counts; statistically significant reduction between E AND A, B, C or D methods ($P < .05$)

TABLE 4 Comparative studies addressing first and second PICO questions; contrast between chemical agents AND brushing AND/OR their combined effect on denture sanitation

Authors (Year)	Type of Study	Control group	Tested hygiene practices	Number of patients	Outcome assessment	Results
de Andrade et al ¹³ (2012)	RCT	Brushing with water (A)	Brushing AND immersion in 0.12% chlorhexidine (B) Brushing AND immersion in 2.0% chlorhexidine (C) (Faculty of Pharmaceutical Sciences of Ribeirão Preto, University of São Paulo)	60 complete denture wearers	Biofilm percentage	Statistically significant reduction between B or C AND A method ($P < .001$) No statistically significant reduction between B and C methods ($P > .001$)
Boscatto et al ¹⁰ (2009)	RCT	Brushing with toothpaste (A) Colgate triple action	Brushing AND immersion in 0.5% sodium hypochlorite for 20 min/once a week (B) (Miyako do Brasil Ind. e Com. LTDA, Guarulhos, SP, Brazil, Batch 24)	20 patients with complete maxillary dentures relined with soft denture-lining material	Biofilm percentage	Statistically significant reduction in A group ($P < .05$) Highest scores in B group
Paranhos et al ²⁰ (2007)	RCT	Rinsing with water (A)	Effervescent tablets (B) (Bonyplus Bonyf AG, Vaduz, Liechtenstein) Brushing with dentifrice (C) (Dentu-Creme, Dentco, Inc., Jersey City, NJ, USA) and soft Johnson and Johnson's toothbrush Brushing with dentifrice/ soft tooth brush (similar to C) AND effervescent tablets (D) Brushing with dentifrice/ soft tooth brush (E) (Oral B size 40 brush; Gillette do Brasil Ltd, Rio de Janeiro, RJ, Brazil) Brushing with dentifrice/ soft tooth brush (similar to E) AND effervescent tablets (F)	36 complete denture wearers	Biofilm percentage	Significantly lower in C or E compared with B method ($P < .001$) Significantly lower in D or F compared with B method ($P < .001$) Greatest biofilm accumulation in vestibular inclines of the labial flanges
Moffa et al ¹⁷ (2016)	RCT	Brushing with coconut soap/ soft toothbrush (A) 3 times/ day/6 months	Brushing with coconut soap/soft toothbrush AND effervescent tablets (B) Brushing with coconut soap/soft toothbrush AND immersion into 2% chlorhexidine digluconate (C)	45 patients with relined maxillary complete dentures	Microbiological analysis	No microbiological growth in B AND C methods after 15 d A method exhibited similar numbers of microbial cells throughout the experiment
Mantri et al ¹⁶ (2013)	Comparative Prospective study	Brushing with soap and brush (A)	Brushing with soap and brush AND immersion in 4% chlorhexidine gluconate (B) (Surgiscrub; ICPA Health Products Private Ltd., Mumbai, India)	30 patients with mandibular complete dentures relined with silicone soft liner	Microbiological analysis	C. <i>albicans</i> counts; no statistically significant reduction after 15 d in diabetics and non-diabetic patients of A group. C. <i>albicans</i> counts; statistically significant reduction after 21 and 30 d in non-diabetic patients of B group

(Continues)

TABLE 4 (Continued)

Authors (Year)	Type of Study	Control group	Tested hygiene practices	Number of patients	Outcome assessment	Results
Sheen and Harrison ²⁵ (2000)	RCT	Brushing with water and immersion in water (A)	Brushing with water AND Effervescent tablets (B) (Fixodent, Procter and Gamble Technical Centres Ltd, Rusham Park, Egham, UK)	40 patients with complete dentures	Biofilm percentage	Biofilm percentage; statistically greater reduction for B method at day 2 (51%) and day 14 (42%) compared with A method ($P < .001$)
Silva-Lovato et al. ²⁶ (2010)	RCT	Brushing with water (A)	Brushing with water AND immersion in Nitr-Adine solution (B) (MSI Laboratories AG, Vaduz, Liechtenstein, Medical Interporous) (Denture, Condor S.A., São Bentodo)	40 patients with complete dentures	Microbiological analysis Biofilm percentage	Yeast counts; statistically significant reduction in B method compared with A method ($P < .001$) Biofilm percentage; significant lower for B group compared with A group ($P < .001$)
Salles et al. ²⁴ (2015)	RCT	Brushing AND immersion into 0.85% saline solution (A)	Brushing AND immersion in 0.25% sodium hypochlorite (Inject Center, Ribeirão Preto, SP, Brazil) Brushing AND immersion in 0.5% sodium hypochlorite (Inject Center) Brushing AND immersion in 10% <i>R. communis</i> oil solution (Institute of Chemistry, University of São Paulo, São Carlos, SP, Brazil)	64 patients with maxillary complete dentures	Microbiological analysis	<i>Candida</i> spp. counts; <i>R. communis</i> solution presented similar action to 0.25% sodium hypochlorite ($P > .05$) inferior action compared to 0.5% hypochlorite ($P < .05$) Gram-negative counts; the 0.25% and 0.5% sodium hypochlorite solutions exhibited similar action ($P < .001$) <i>R. communis</i> solution proved to be ineffective ($P < .001$) 0.5% sodium hypochlorite solution was the most effective

TABLE 5 Controlled clinical trials addressing second PICO question and investigating the effect of brushing on denture sanitation

Authors (Year)	Type of study	Control group	Tested hygiene practices	Number of patients	Outcome assessment	Results
Fernandes et al ²⁸ (2007)	Comparative controlled clinical trial	Rinsing with water (A)	Brushing with 3 different toothbrushes AND dentifrice (Bitufo; Bitufo, Itupeva, São Paulo, Brazil) (B) (Medic Denture; Condor SA, São Bento do Sul, SC, Brazil) (C) (Colgate; Colgate-Palmolive, São Bernardo do Campo, SP, Brazil) (D) Corega; Brite Stafford-Miller Indústria Ltda, Rio de Janeiro, RJ, Brazil	33 complete denture wearers	Biofilm percentage Microbiological analysis	Biofilm percentage removal; no statistically significant difference between the brushes ($P < .01$) Yeast counts; no statistically significant difference for each denture brush ($P > .01$)
Salles et al ²³ (2007)	Comparative controlled clinical trial	Rinsing with water (A)	Brushing with specific paste for complete dentures (B) (Corega Brite Stafford; Miller Indústria Ltda; Rio de Janeiro, Brasil) Brushing with neutral pH gel soap (C) (Selvatica, Farmacia Homeopatica e de Manipulacão Ribeirão Preto, São Paulo, Brazil)	45 patients with complete dentures	Biofilm percentage	Biofilm percentage; mandibular complete dentures presented significantly greater mean biofilm percentage than the maxillary ones Biofilm percentage removal; B method more effective than C and A methods ($P < .001$)
Paranhos Hde et al ¹⁹ (2013)	Cross-over RCT	Brushing with water(A)	Brushing with denture dentifrice (B) (Corega Brite denture dentifrice (CB; Stafford-Miller Indústria Ltda, Rio de Janeiro, RJ, Brazil) Brushing with neutral liquid soap (C) (JOB-Quimica Ltda, Sao Paulo, SP, Brazil) Brushing with denture dentifrice AND artificial saliva (D) (Oral Balance, OB; Laclede do Brasil Ltda., Sao Paulo, SP, Brazil)	23 patients with complete dentures	Biofilm percentage Microbiological analysis	Biofilm percentage; mandibular dentures presented significantly greater than the maxillary ones ($P < .05$) Biofilm percentage removal; D method more effective than A, B or C method ($P < .05$) Yeast counts; no statistically significant difference among the 4 methods

TABLE 6 Controlled clinical trials addressing second PICO question and investigating the effect of chemical agents on denture sanitation

Authors (Year)	Type of study	Control group	Tested hygiene practices	Number of patients	Outcome assessment	Results
Naibant et al ³⁰ (2008)	RCT	Rinsing with water (A)	Immersion in 0.2% digluconate chlorhexidine (B) (Klorhex, Drogan Doğa kaynakları ilac Hammaddeleri Sanayi ve Tic. A. Ş., Ankara, Turkey) Effervescent tablets (C) (Fittydent Mag, Hoeveler and Co. Gmbh, Geinberg, Germany)	45 complete denture wearers	Microbiological analysis	<i>Candida</i> spp.; the colonization rate on dentures was reduced from 82.2% to 68.8% using B and C methods <i>Candida</i> spp counts; similar adherence of B and C methods on dentures
Dyuck et al ¹⁵ (2013)	RCT	Immersion in water overnight(A)	DRY condition overnight (B) Immersion in water AND effervescent tablets overnight (C) (Corega Tabs antibacterial (GlaxoSmithKline Consumer Healthcare SA, Genval, Belgium)	51 with mandibular complete dentures	Microbiological analysis	Bacterial counts; statistically lower for C method compared with A ($P < .05$) <i>Candida</i> spp. counts; significant lower amounts for C method compared with A method ($P < .05$)
de Sousa Porta et al ¹⁴ (2015)	Single-cohort/prospective study	Baseline (before immersion in 0.5% NaOCl solution)	Immersion in 0.5% NaOCl solution for 3 min daily (Farmacia Proderma, Piracicaba, Brazil)	15 complete denture wearers	Microbiological analysis	Microorganisms' counts; significant reduction after 30, 60 and 90 d ($P < .001$)
Srinivasan and Gulabani ²⁷ (2010)	Cross-over RCT	Rinsing with water (A)	Effervescent tablets (B) (Corega, GlaxoSmithKline, Waterford, Ireland) Effervescent tablets + 0.2% digluconate chlorhexidine Oral rinse (C) preparation (Corsodyl, GlaxoSmithKline Consumer Healthcare, Brentford, UK)	24 patients with complete dentures	Microbiological analysis	Microorganisms' counts; significant reduction in B and C methods ($P < .001$) After first week, no statistically significant difference between the method B and method C ($P > .05$)

TABLE 7 Controlled clinical trials addressing second PICO question and investigating the effect of irradiation on denture sanitation

Authors (Year)	Type of study	Control group	Tested hygiene practices	Number of patients	Outcome assessment	Results
Ribeiro et al ²² (2009)	RCT	Baseline (before microwave exposure)	Irradiation once for 3 min at 650 W (A) Irradiation once for 2 min at 650 W (B) Domestic microwave oven (Model Sensor Crisp 38, Brastemp, Double Emission System, Manaus, AM, Brazil) and Photodynamic therapy (PDT) P100G/ P50G/P100S and P50S (Photogem, Moscow, Russia) combined with LED device	30 patients with maxillary complete dentures	Microbiological analysis	A method resulted in denture sterilization B method resulted in denture disinfection <i>Candida</i> spp., <i>mutans streptococci</i> , <i>staphylococcus</i> spp. significant decrease in B method ($P < .05$) <i>Candida</i> spp. were the most frequent microorganism (76.6%), followed by <i>Staphylococcus</i> spp. and <i>Mutans streptococci</i> (66.6% and 53.3%)
Ribeiro et al ²¹ (2012)	RCT	Baseline (before microwave exposure)	Photodynamic therapy (PDT) P100G/ P50G/P100S and P50S (Photogem, Moscow, Russia) combined with LED device	60 patients with maxillary complete dentures	Microbiological analysis	All PDT regimens eliminated over 90% of microorganisms from dentures; significant reduction in microorganism counts ($P < .05$) <i>Candida</i> spp. was the most frequent microorganism (60.0%), followed by <i>Mutans streptococci</i> (53.3%) and <i>Staphylococcus</i> spp. (48.3%)

significant reduction in *Candida* spp., *mutans streptococci* and *staphylococcus* spp. counts.²² With regard to PDT, this sanitation technique reduced over 90% of the microorganisms on the dentures including *Candida* spp.²¹ (Table 7).

3.3.7 | Colour stability

Two clinical trials examined the colour stability of relined dentures following disinfection via microwave disinfection and immersion in perborate and chlorhexidine digluconate 2%, solutions at observational periods of 1 year and 6 months, post-placement, respectively.^{60,61} No significant alterations in colour were noticed in relined dentures subjected to microwave irradiation, taking into account the values of spectrophotometer and NBS units.⁶¹ On the other hand, significant changes in colour parameters, including CIE (Commission Internationale de l'Eclairage) colour differences L*a*b" system coordinates (DL, Da and Db) and National Bureau Standards (NBS) values, were observed in relined dentures that were disinfected by perborate and chlorhexidine digluconate 2% solutions⁶⁰ (Table 8). However, relined dentures subjected to immersion in chlorhexidine digluconate 2% presented perceivable and marked colour changes earlier at 7 days and 1 month, respectively, compared with the corresponding dentures that were immersed in perborate solution. No significant differences in colour changes over time were observed in complete dentures that were immersed in 0.5% sodium hypochlorite (NaOCl) solution for 3 minutes daily for 90 days¹⁴ (Table 8).

3.3.8 | Dimensional stability

The dimensional stability of dentures following microwave irradiation was examined either indirectly via assessment of occlusal pressure pattern of dentures⁵⁸ or directly via measurement of the linear dimensional alterations of acrylic denture base.⁵⁹ The disinfection protocol dictating a 3-minutes irradiation at 650 W for 3 times per week achieved sterilization of dentures and produced dimensional alterations $<1\%$ ⁵⁹ (Table 9). Finally, the study of Basso et al⁵⁸ demonstrated that the aforementioned disinfection protocol did not alter the occlusal pressure pattern of complete dentures. Furthermore, the fact that no sore spots were identified and further complaints were registered during the follow-up period indicated that the denture adaptation remained similar (Table 9).

3.3.9 | Hygiene habits/attitudes

From the available scientific evidence, brushing of the removable dentures represents the most commonly applied cleansing method of removable denture wearers (Table 10). Dentures cleaned 2-3 times a week were poor in cleanliness, whereas dentures cleaned 2-3 times a day were found to be excellent.⁴² Although cleaning tablets represented a highly recommended hygiene practice by dental healthcare professionals, only $\frac{1}{4}$ of denture wearers reported this approach as frequently applied.³² In particular, 9 studies reported that approximately over 50 per cent of denture wearers did not remove their

TABLE 8 Controlled clinical trials addressing third PICO question and investigating the effect of hygiene practices on denture colour stability

Authors (Year)	Type of study	Control group	Tested hygiene practices	Number of patients	Outcome assessment	Results
Moffa et al ⁶⁰ (2011)	RCT	Brushing with coconut soap and soft toothbrush (A)	A method + immersion in warmed water solution with effervescent tablet (B) (Corega Tabs, GlaxoSmithKline Brasil Ltda, Rio de Janeiro, RJ, Brazil) A method + immersion in chlorhexidine digluconate 2% solution (C) (Arte & Cie`ncia, Farmacia de Manipulac~o, Araraquara, SP, Brazil)	45 patients with maxillary complete dentures relined with hard chair side reline resin	Spectrophotometer Color Guide 45/0 (BYK-Gardner, Santo Andre', SP, Brazil) L*a*b* system NBS units	After a 6-month follow-up period; statistically higher values of colour changes (ΔL , Δa , Δb) in C group compared with A and B methods A and C group tended to become lighter over time; B group tended to become darker/ more pronounced effect at 3 and 6 months, respectively DE* mean values; no significant differences were found among the tested methods ($P > .05$) B method displayed slight colour changes at 7 d, perceivable at 15 d and 1 month and marked at 3 and 6 months (NBS units)@C method displayed perceivable colour changes at 7 and 15 d and marked for the periods at 1, 3 and 6 months
de Sousa Porta et al ¹⁴ (2015)	Single-cohort/ Prospective study	Baseline (before exposure to NaOCl solution) (A)	Brushing + immersion in 0.5% NaOCl solution (Farmacia Proderma, Piracicaba, Brazil) for 3 min daily	15 complete denture wearers	Spectrophotometer (CM-700d; Konica Minolta Sensing Inc. Tokyo, Japan) L*a*b* system NBS units	After the baseline, 30, 60 and 90 d; no significant differences in colour changes over time for each group ($P > .05$)
Ribeiro et al ⁶¹ (2011)	RCT	Brushing with coconut soap and soft toothbrush (A)	Brushing with coconut soap and soft toothbrush AND Microwave disinfection once a week (B)	40 patients with maxillary complete dentures relined with hard chair side reline resin	Spectrophotometer (Color Guide 45/0') L*a*b* system NBS units	After 1-y follow-up; noticeable colour changes observed for A method; slight colour change was observed for B method Statistically significant differences between L* values initially and after 3 months, between 15 d and 3 months and between 15 d and 1 y ($P < .05$) No significant differences were observed between groups and time for the a* and b* parameters ($P > .05$)

TABLE 9 Controlled clinical trials addressing fourth PICO question and investigating the effect of hygiene practices on denture dimensional stability

Authors (Year)	Type of Study	Control group	Tested Hygiene Practices	Number of patients	Outcome assessment	Results
Basso et al ⁵⁸ (2010)	RCT	Baseline (before exposure to microwave irradiation)	Microwave disinfection 3minX650W once per week × 4 wks (A) 3minX650 W 3 times per week × 4 wks (B)	40 patients with maxillary complete dentures	Linear dimensional stability Measurement of the distances and areas of reference points (buccal cusps of the first premolars and the distobuccal surfaces of the second molars)	Dimensional changes < 1% No significant clinical findings Method B significantly greater shrinkage than method C
Basso et al ⁵⁹ (2015)	RCT	Baseline (before exposure to microwave irradiation)	Microwave disinfection 3minX650W once per week × 4 wks (A) 3 min × 650 W 3 times per week × 4 wks (B)	40 complete denture wearers	T-Scan III (Tekscan, South Boston, MA)	No significant differences between A and B methods during observation period (P > .05) All patients demonstrated soft tissue or dental arches with no sore spots

removable prostheses overnight.^{33-35,37,39,40,45,50,68} Furthermore, a significant (30-60%) portion of removable denture wearers brush their removable prostheses once daily.^{31,35,36,38,39,42,44,53,68} In terms of the relationship between denture hygiene and patient's sex, female patients exhibited "good" and "fair" degrees of hygiene more often than males.³⁶ The frequency of cleaning dentures and using cleansing tablet was also higher in females than in males.^{35,69} Finally, female denture wearers remove their prosthesis overnight more often than male.^{31,33}

3.4 | Study quality

All the articles included in the present systematic review were prospective CCTs evaluating the effectiveness of the available hygiene interventions and their impact on prosthesis colour and dimensional stability. Table 11 depicts the scores of Cochrane quality assessment tool for the randomized controlled trials, ranging from low to high risk of bias studies.⁶³ With respect to the quality of N-RCTs, according to MINORS criteria ratings, the included clinical trials were evaluated as moderate bias risk studies.⁶⁴ None of those clinical trials involved prospective calculation of the study size and blind evaluation of study endpoints (Table 12).

3.5 | Grading the body of evidence

Table 13 summarizes the ratings of GRADE system criteria about the quality of the evidence and the strength of the recommendations towards the effectiveness of mechanical hygiene interventions, chemical agents as well as their combined effect. The risk of bias varied among the included CCTs from low to high, and reporting bias was considered to be possible. The variability in the results of different CCTs in conjunction with the overlapping confidence intervals creates any "inconsistency" in the available scientific evidence. Furthermore,

the presence of wide confidence intervals mars the quality of the data leading to "imprecision." As direct comparisons among the study populations, outcomes and interventions were observed, it can be assumed that the results are "generalizable." In terms of biofilm removal, the level of certainty was rated as "moderate" resulting in a mild recommendation in favour of the combination of mechanical and chemical hygiene practices compared with chemical agents alone. With respect to microbiological analysis, the level of certainty was also rated as "moderate" favouring mildly the combination of mechanical and chemical hygiene interventions compared with mechanical hygiene practices alone.

4 | DISCUSSION

From the reviewed scientific evidence in the field of hygiene approaches in Removable Prosthodontics, some conclusions can be drawn. With regard to the first and second PICO questions of this systematic review, the available comparative RCTs investigating the effectiveness of mechanical hygiene interventions including ultrasound vibration and/or brushing in conjunction with immersion in alkaline peroxide solutions advocate the combination of the aforementioned in order to achieve optimal sanitation outcomes.^{11,12,18,29} As dentures subjected only to ultrasonic vibration in distilled water did not result in remarkable alterations of *C. albicans*, *Mutans streptococci* or total bacterial counts, it can be assumed that the effect of cavitation bubbles in the aqueous solution is inefficient to diminish the number of the examined microbial species.^{12,18,30} Therefore, the effectiveness of the ultrasonic cleaning method is associated with the supplementary chemical action of the immersion solution rather than with the mechanical impact of the ultrasound device.^{12,18,29} Taking into consideration the design of all the available RCTs relative to the frequency and the duration of different type of hygiene

TABLE 10 Studies investigating removable denture wearers' attitudes and hygiene habits worldwide

Study (Year)	Country	Patients	Commonly Applied Disinfection Method	Frequency	Overnight removal
Apratim et al ³¹ (2013)	Pakistan	230 complete denture wearers	Water and brushing (31.30%) Water and cleansing tablets (10.40%) Water only (35.10%) Water and brush and soap (23.20%)	44.7% once daily 39.60% once/twice a week 15.7% occasionally	-
Axe et al ³² (2016)	Japan, USA, Italy, Brazil, India	1463 denture wearers	Brushing with toothpaste (40-60%) Mouthwash (25%) Denture tablets (12-24%)		
Barreiro et al ³⁴ (2009)	Brazil	231 with removable dentures	Brushing their dentures using dentifrice (94.4%). Other products 5.6% (mouthrinses, soap, sodium bicarbonate and others)	Thrice/day (74.9%) Twice/day (20.3%) Once/day (4.8%)	Yes 32.3% No 67.7%
Baran and Nalçacı ³³ (2009)	Turkey	310 complete denture wearers	Brushing Toothbrush (45.2%) Toothbrush and paste (48.4%) Chemicals (5.8%)	Denture immersion Water (42.9%) Chemicals (1.6%) Not removed (55.5%)	Yes 44.8% No 55.2%
Chowdhary and Chandraker ³⁶ (2011)	India	125 complete denture wearers	Brushing with toothbrush (94.26%) Brushing with soap (36.6%) Brushing with toothpaste (28.8%) Brushing with water (34.4%)	Once/day (69.6%)	Yes (63.4%) No (36.6%)
De Castellucci Barbosa et al ³⁷ (2008)	Brazil	150 complete denture wearers	Toothbrush (94.6%) Toothpaste (88.7%) Disinfecting substance (16.8%) Water (8.0%) Soap (8.0%)	>Thrice/day (17.33%) Thrice/day (45.33%) Twice/day (28.67%) Once/day (8.67%)	Yes (36%) No (64.4%)
Cakan et al ³⁵ (2015)	Nigeria	145 RPD wearers	Brushing (57.9%) • Baking soda (2.2%) • Detergent (4.1%) • Soap (12.5%) • Only water (20.8%) • Toothpaste (60.4%) Soaking (33.7%) • Soap (24.6%) • Cleansing tablet (39.3%) • Baking soda (4.9%) • Sodium hypochlorite 16 (26.3%) Brushing + soaking (8.2%)	Once/day (60.7%) Twice/day (20%) Thrice/day (19.3%)	Yes (46.9%) No (53.1%)

(Continues)

TABLE 10 (Continued)

Study (Year)	Country	Patients	Commonly Applied Disinfection Method	Frequency	Overnight removal
Dikbas et al ³⁸ (2006)	Turkey	234 patients with removable prostheses	Brushing with toothpaste (40.59%) Soaking (5.6%) Brushing and soaking (38.03%)	Once/day (38.5%) Twice/day (22.6%) Thrice/day (8.9%) Twice/thrice weekly (10.3%) Once weekly (13.2%)	-
De Vischere et al ⁶⁶ (2006)	Belgium	290 patients with removable prostheses	Toothbrush (81.4%) Toothpaste (70.9%) Denture cleaning tablets (44.9%) Denture brush (19.3%)	-	-
Ercalik-Yalcinkaya et al ³⁹ (2015)	Turkey	400 patients with removable prostheses	Brushing with toothpaste/soap brushing (9.5%) Brushing with toothpaste or soap (85.8%) Brushing with water (4.8%)	Thrice/day (29.5%) Twice/day (30.8%) Once/day (32.3%)	Yes (35.5%) No (64.5%)
Ferruzzi et al ⁴⁰ (2015)	Brazil	48 patients with complete dentures	Brushing with toothpaste (84.6-88.2%) Brushing with soap (42.86%)	-	Mandibular denture Yes (61.9%) No (38.1%) Maxillary denture Yes (43.2%) No (56.8%)
Gosavi et al ⁶⁷ (2013)	India	178 patients	-	Daily (48.8%) Weekly (31.30%) Monthly (13.20%) Rarely (7.10%)	Yes (48%) No (42%)
Jeganathan et al ⁴¹ (1997)	Singapore	75 patients with maxillary complete dentures	Brushing (51-89%) Rinsing (3%) Brushing and denture cleanser (8-46%)	-	-
Kanli et al ⁴² (2005)	Turkey	42 patients with maxillary dentures	Brushing and soaking (21.4%) Brushing (78.6%) 2-3 times/day (31%)	Once/day (26.2%) 2-3 times/week (42.8%)	-
Khasawneh and al-Wahadni ⁴³ (2002)	Jordan	321 patients with removable prostheses	Brushing with toothpaste/soap	-	-
Kossioni et al ⁶⁸ (2011)	Greece	106 denture patients	-	Once/day 37.6%	Yes (44.3%) No (55.7%)
Kulak-Ozcan et al ⁴⁴ (2002)	Turkey	70 complete denture wearers	Brushing only (57.1%) Soaking in solution only (5.7%) Soaking in water only (17.1%) Brushing and soaking (8.6%) Nothing (11.5%)	<Once/day (25.7%) Once/day (28.6%) >Once/day (45.7%)	-

(Continues)

TABLE 10 (Continued)

Study (Year)	Country	Patients	Commonly Applied Disinfection Method	Frequency	Overnight removal
Marchini et al ⁴⁵ (2004)	Brazil	236 complete denture wearers	Brushing 98.7% Brushing only with toothpaste (79.7%) Ordinary soap/ toilet soap, sodium bicarbonate and sodium hypochlorite < 5% No (73.7%)	2.9 times/day	Yes (26.3%)
Milward et al ⁴⁶ (2013)	United Kingdom	196 with removable partial dentures	Toothbrush (72.4%) Toothpaste (35.2%) Soap (24.5%) Cleansing tablets (38.3%)	Once (10.2%) Twice/day (55.6%) >3 times/d (34.2%)	Yes (90.1%) No (9.2%)
Nevalainen et al ⁴⁷ (1997)	Finland	338 elderly with removable dentures	Brushing with water (74%) Brushing with tooth/denture paste (22%) Rinsing with water (15%) Disinfectants (3%)	≥Once/day (96-98%)	-
Osmari et al ⁴⁸ (2015)	Brazil	243 participants with complete or removable partial dentures	Brushing (99.6%) Brushing with dentifrice (90.9%)	≥ 3 d (71.1%)	-
Peltola et al ⁴⁹ (1997)	Finland	47 complete denture wearers	Peroxide cleanser Denture brush/water	Twice daily	-
Peracini et al ⁵⁰ (2010)	Brazil	106 patients with removable prostheses	Brushing with dentifrice (84.91%) Brushing (100%)	≥ 3/d (73.58%)	Yes (41.51%) No (58.49%)
Pietrokovski et al ⁵¹ (1995)	Israel	249 patients with complete dentures	Brushing (toothbrush/laundry brush with a cleaning agent (toothpaste, mouth wash, denture effervescent, denture cleaning solution, mild detergent, running water)	≥ Twice/day (96%)	-
Roshene et al ⁵² (2015)	India	50 patients with complete dentures	Toothbrush with water (74%)	Twice/day (62%)	-
Ryu et al ⁵³ (2015)	Japan	54 elderly with complete dentures	Brushing	Zero/day (15%) Once/day (30%) Twice/day (18%) Thrice/day (37%)	-
Saarela et al ⁶⁹ (2013)	Finland	38% / 1475 frail older assisted living residents	-	Daily (89%)	-

(Continues)

TABLE 10 (Continued)

Study (Year)	Country	Patients	Commonly Applied Disinfection Method	Frequency	Overnight removal
Sadig et al ⁷⁰ (2010)	Saudi Arabia	48 patients with complete dentures 23 RPD wearers	Washing (60.6%) Soaking (15.4%) Toothbrush (24%)		
Saha et al ⁵⁴ (2014)	India	500 denture wearers	Brushing with water (47%) Water only (25%) Brushing with water and soap (19%) Water and cleansing tablet (9%)	Once/day (52.50%) Once/twice/week (19.30%) Occasionally (28.20%)	
Takamiya et al ⁵ (2011)	Brazil	224 complete denture wearers	Brushing with toothpaste (46.87%) Soaking in a solution (sodium hypochlorite, commercial denture cleaner, etc.) (1.79%) Brushing with toothpaste and soaking in a sodium hypochlorite solution (17.86%) Soaking and rinsing (5.36%) Association of 2 or more methods (20.54%)		Yes (88%) No (12%)

interventions, these correspond to 2 min/3 times daily for brushing, 5- to 20-minutes immersion of dentures in warm (37-50°C) alkaline peroxide solutions daily and 15-minute vibration for ultrasound cleansing method.^{11,12,18,29} With regard to the investigation of brushing along with a short-term (5-20 minutes) denture immersion in alkaline peroxide or sodium hypochlorite or chlorhexidine gluconate or sodium lauryl sulphate (SLS) solutions, this was also documented to be superior to exclusive brushing, indicating the need for introduction of an adjunctive chemical agent to enhance sanitation.^{13,16,17,20,24-26,29} From the scope of biochemistry, the resistance of both *Streptococcus mutans* and *C. albicans* is ascribed to their morphological features which involve a thick cell wall made up of peptidoglycan and a thick multilayered cell wall, respectively.⁷¹

With respect to the findings of all the available CCTs investigating the effectiveness of exclusively 1 type of hygiene practices, these can be summarized by the following endpoints. In terms of biofilm percentage reduction, 2 studies demonstrated that brushing with dentifrice displayed superior performance over brushing with neutral soap.^{19,23} The type of the assisted brushing product or toothbrush has no crucial impact on the hygiene outcomes considering the results from microbiological analysis.^{19,28} With respect to the available chemical hygiene agents, denture immersion in 0.2% digluconate chlorhexidine, 0.5% sodium hypochlorite and/or effervescent alkaline peroxide solutions led to a significant reduction in total CFUs.^{14,15,27,30} The antimicrobial properties of NaOCl are attributed to the action of hydroxyl ions and chloramination including irreversible inactivation of bacteria enzymatic sites and dissolution of mucin and other organic substances.⁷² On the other hand, in the cases of soft denture-lining materials, the effect of NaOCl can be deleterious as the irregularities created on the lining surface enhance the adherence of *C. albicans* and consequently the formation of increased amount of biofilm.^{10,73} The lethal mechanism of action of chlorhexidine is attributed to the disruption of cell osmotic equilibrium. In particular, chlorhexidine binds to the negatively charged bacterial wall, disrupts bacteria cell membrane and leads to cytoplasmatic precipitation.^{74,75}

The results of this systematic review corroborate with the current guidelines of American College of Prosthodontists, suggesting that removable dentures be cleaned daily by soaking and brushing with an effective and non-abrasive denture cleanser.⁷⁶ In the event of denture wearers with restricted motor capacity or cognitive impairment—mainly elderly and/or nursing home residents—a denture cleaning method such as ultrasound cleaning that reduces the manual effort is recommended.¹⁸ Although an ultrasonic device requires cost to be expensed, it can be assumed that ultrasonic cleaning combined with immersion in a denture cleanser solution is indicated in hospitals and nursing homes for the elderly.

Comparing the biofilm levels between the maxillary and mandibular complete dentures, it was observed that the mandibular prostheses presented greater biofilm levels.^{19,23,28} The higher retention of maxillary denture in conjunction with its shape could be a reasonable explanation of this fact. Based on clinical findings, higher biofilm deposits were greater in regions such as palatal rugae, maxillary tuberosities and anterior vestibular regions. In mandibular complete

TABLE 11 Risk of bias for randomized controlled trials (RCTs) based on cochrane's tool

Authors (Year)	Selection bias		Performance bias		Detection bias	Attrition bias	Reporting bias		Total
	Random sequence generation	Allocation concealment	Blinding of participants	Blinding of personnel	Blinding of outcome assessors	Data integrity	Selective report	Other sources of bias	
Andrade et al ¹³ (2012)	+	-	-	-	-	+	+	+	High
Andrade et al ¹² (2011)	+	-	-	-	-	+	+	+	High
Cruz et al ⁸ (2011)	+	-	-	-	+	+	+	+	High
Duyck et al ²⁹ (2016)	+	+	+	+	+	+	+	+	Low
Duyck et al ¹⁵ (2013)	+	?	+	+	+	+	+	?	Low
Moffa et al ⁶⁰ (2011)	+	+	-	?	+	+	+	+	Moderate
Moffa et al ¹⁷ (2016)	+	-	-	+	+	+	+	+	High
Nalbant et al ³⁰ (2008)	+	-	-	-	-	+	+	+	High
Nishi et al ¹⁸ (2014)	+	-	-	?	+	+	+	+	High
Paranhos et al ²⁰ (2007)	+	-	-	-	+	+	+	?	High
Paranhos Hde et al ¹⁹ (2013)	+	-	-	-	-	+	+	?	High
Ribeiro et al ²³ (2009)	+	-	-	+	?	+	+	?	High
Ribeiro et al ⁶¹ (2011)	+	+	-	?	+	+	+	+	Moderate
Ribeiro et al ²¹ (2012)	+	-	-	+	?	+	+	+	High
Salles et al ²³ (2015)	+	+	+	+	+	-	+	?	Low
Sheen and Harrison ²⁵ (2000)	+	?	?	+	+	-	+	+	High
Silva-Lovato et al ²⁶ (2010)	+	-	-	-	-	+	+	?	High
Basso et al ⁵⁸ (2010)	+	-	?	-	-	+	+	+	High
Basso et al ⁵⁹ (2015)	+	-	?	?	+	+	+	+	High
Srinivasan and Gulabani ²⁷ 2010	+	-	-	-	-	+	+	?	High
Boscato et al ¹⁰ (2009)	+	-	-	-	-	+	+	?	High

+ depicts the presence; - depicts the absence; ? is not clarified.

dentures, greater biofilm levels were observed in the region of the retromolar pad and the anterior internal regions (vestibular and lingual).²³

Microwaving at 650 W for 3 minutes resulted in clinical sterilization of complete dentures. Besides, microwave irradiation at 650 W for 2 minutes produced also denture disinfection eliminating

TABLE 12 Risk of Bias for Non-randomized Controlled Trials (N-RCTs) based on MINORS criteria

Author	A clearly stated aim	Inclusion of consecutive patients	Prospective collection of data	Endpoints appropriate to the aim of the study	Unbiased assessment of the study endpoint	Follow-up period appropriate to the aim of the study	Loss to follow-up less than 5%	Prospective calculation of the study size	An adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses	Score
Salles et al ²³ (2007)	2	2	2	2	0	2	2	0	2	2	2	2	20/24
Fernandes et al ²⁸ (2006)	2	2	2	2	0	2	2	0	2	2	2	2	20/24
Mantri et al ¹⁶ (2013)	2	2	2	2	0	2	2	0	2	2	2	2	20/24
De Sousa Porta et al ¹⁴ (2015)	2	2	2	2	0	2	2	0	2	2	2	2	20/24

Items with 0 score (not reported), 1 (reported but inadequate) and 2 (reported and adequate). The global ideal score is 24 for comparative studies.

the total microbial counts.²³ Up to date, the exact mechanism of action of microwave irradiation has not been specified. The lethal effect of irradiation has been attributed either to the heat produced by the microwaves (thermal effect) or the interaction between the electromagnetic field created by the microwaves and the cell molecules, resulting in molecular, mechanical or selective heating mechanisms.⁷⁷⁻⁷⁹

Photodynamic therapy represents an innovative method for disinfection of removable prostheses reducing over 90% of the microorganisms on the dentures.²¹ The basic principle of this disinfection method relies on the irradiation of a substance known as a photosensitizer (PS) with a light source, which causes cell death via the production of reactive oxygen species such as singlet oxygen.²¹

Detailing the current scientific evidence, no RCTs have been carried out in order to investigate the effectiveness of hygiene interventions in patients wearing removable partial dentures, implant-supported overdentures and maxillofacial prostheses. For instance, as the function of obturators involves separation of the oral, antral and nasal cavities, the effectiveness of hygiene interventions in those special prosthetic restorations should be the objective of further scientific research.

Perceptible colour alterations in acrylic resin base subjected to disinfection could create social constraints to denture wearers and greater cost for the fabrication of new prostheses. The available scientific evidence about the impact of disinfection on colour and dimensional stability of acrylic removable dentures under clinical conditions is scarce. Microwave disinfection produced minor colour changes in the relined dentures assuming that the lower content of residual monomer of autopolymerizing reline acrylic resin after microwave irradiation is ascribed to lower rates of oxidation. Therefore, the intrinsic colour alterations due to water absorption and hydrophilic characteristics of the resin were found to be decreased.⁸⁰⁻⁸² Time is a critical factor for colour instability in relined dentures, and regardless of the application of a specific chemical agent, the possibility of staining of a reline material is possible, taking into consideration the bleaching effect of brushing with coconut soap and soft toothbrush. Another parameter that requires further investigation is the critical concentration of chlorhexidine that results in staining on denture materials under clinical conditions. Finally, the study of de Sousa Porta et al¹⁴ demonstrated that the influence of 0.5% NaOCl on the colour of the dentures after a 3-month observational period was not significant. Repeated colour evaluations showed that the colour difference values were lower than 3.7, which represents the lowest acceptable threshold.⁸²⁻⁸⁴ Colour stability of removable dentures represents a physical property that is affected to a certain degree by factors such as the salivary pellicle in conjunction with foods and beverages consumption. As no in vitro study design can duplicate these conditions, further and more longitudinal clinical trials investigating the impact of hygiene interventions on colour stability of dentures are required.

As only 2 clinical studies have investigated the effect of microwave irradiation on the dimensional stability of removable dentures,^{58,59} further longitudinal clinical trials should be conducted in order to

extrapolate more clear conclusions about the effect of hygiene interventions on dimensional stability of removable prostheses.

From the available scientific evidence, brushing of the removable dentures represents the most commonly applied cleansing method of removable denture wearers (Table 7). Although the frequency of cleaning does not necessarily indicate efficiency, most denture wearers, and especially elderly, are not sufficiently informed about proper denture care. Taking into consideration the registered values for the frequency of the applied hygiene methods and the continuous or nocturnal wearing of removable dentures, it can be concluded that evidence-based hygiene guidelines should be communicated to the patients (Table 7). A significant portion of denture wearers—exceeding 50 per cent—did not remove their removable prostheses overnight. Based on the findings of the study of Iinuma et al³, this oral hygiene behaviour has been associated with a 2.38-fold higher risk of serious pneumonia events in community-living very elderly.

With regard to study search strategy, potential limitations of this systematic review could be the English language, the number of online databases as well as the time frame for the identification of the available scientific evidence. However, the authors performing a 20-year period literature search attempted to collect the most updated data about the current hygiene practices and commercially available hygiene agents.

5 | CONCLUSIONS

Within the limitations of this systematic review, the current study demonstrated that the combined application of different types of hygiene practices in removable prostheses, namely mechanical interventions in conjunction with chemical agents, achieves optimal outcomes in terms of hygiene effectiveness. Despite the limited number of existing clinical trials investigating the effect of hygiene practices on colour and dimensional stability of removable dentures, it seems that microwave disinfection leads to insignificant alterations in dimensional stability of prostheses. Colour instability of dentures subjected to hygiene interventions is dependent on the critical concentration of chemical solutions as well as the duration of the chemical agent application. Denture brushing is the most commonly applied hygiene practice among denture wearers worldwide. The registered denture wearers' habits and attitudes towards the hygiene of their removable prostheses indicate that evidence-based removable prostheses hygiene guidelines should be communicated to patients.

6 | CLINICAL RELEVANCE

6.1 | Scientific rationale for study

This systematic review was conducted to inform oral healthcare providers about the effectiveness of the hygiene modalities and their effect on prosthesis colour and dimensional stability under clinical conditions as well as to document the current patients' attitudes and habits towards removable dentures hygiene so as to identify potential deficiencies in oral health education.

6.2 | Principal findings

Mechanical interventions combined with chemical agents achieve optimal sanitation outcomes. Despite the limited amount of clinical evidence, dimensional stability of dentures subjected to microwave disinfection remains unaltered. Critical concentrations of cleansing solutions along with the duration of their implementation influence the serviceability of dentures regarding colour stability. Denture wearers' attitudes and habits are not conformed to the recommended guidelines.

6.3 | Practical implications

Further clinical studies should be conducted investigating the effect of hygiene interventions on prosthesis colour and dimensional stability. Evidence-based hygiene guidelines for removable prostheses should be communicated to the patients.

AUTHOR CONTRIBUTIONS

Both authors (S.P. and G. P.) designed, performed and analysed this systematic review without sponsoring.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

ORCID

S Papadiochou  <http://orcid.org/0000-0003-4794-9398>

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