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SYSTEMATIC REVIEW

Antimicrobial properties of denture adhesives: A scoping review

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ABSTRACT

Statement of problem. Denture adhesives have been a focus in prosthodontic research for many years because of the consistently high demand for these products. However, systematic investigations into their antimicrobial properties or effectiveness are limited.

Purpose. The purpose of this scoping review was to investigate and evaluate articles on the antimicrobial activity of denture adhesives.

Material and methods. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to describe the result of the scoping review. Four electronic databases were searched for articles in the English language up to October 2023.

Results. A total of 597 published articles were identified, and 40 met the selection criteria for review. Of these, 17 articles reported that denture adhesives with added antimicrobial agents demonstrated antimicrobial effects. Eight articles detailed the antimicrobial effectiveness of denture adhesives that did not contain added antimicrobial agents. Additionally, 11 articles compared the antimicrobial effectiveness of denture adhesives without additional agents. The results varied, with some adhesives showing antimicrobial effects while others with similar compositions did not. Studies indicate that some denture adhesives exhibit antifungal or antibacterial effects; however, whether these effects are associated with the included antimicrobial agents or components or other ingredients is unclear.

Conclusions. Although extensive studies have attempted to evaluate the antimicrobial efficacy of commercially available denture adhesives and to incorporate additional antimicrobial agents into them, whether the incorporated antimicrobial agents are effective or whether the effects are caused by other ingredients remains unclear. (J Prosthet Dent 2025;133:445.e1-e10)

The Glossary of Prosthodontic Terms[1] defines a denture adhesive as "a material used to adhere a denture to the oral mucosa." While denture adhesives have a significant and lengthy history dating back to the late 1700s,[2–4] their formal recognition within the dental community did not occur until the early 1900s.[2,5,6]

Advances in denture adhesive technology have improved denture functionality and stability,[5] and they are now widely used by denture wearers worldwide[7,8] to improve fit, comfort, mastication, and self-confidence.[9] Approximately 15% to 30% of denture users have been reported to regularly use a denture adhesive,[10,11] with over 5 million users in the U.S. alone.[12,13] Traditionally, denture adhesives were primarily recommended as a solution for ill-fitting or poorly constructed dentures. However, the current recommendation is to consider the use of denture adhesives for all complete dentures given the substantial benefits they offer to denture wearers,[5] as well as for individuals with resorbed ridges,[14,15] xerostomia, or salivary dysfunction.[16]

The primary mechanism of water-based denture adhesives such as those containing alginate and chitosan[17] involves physical and chemical reactions[18] such as swelling and acquiring adhesive properties. When these materials encounter and absorb water, saliva, or other oral fluids, they can swell by 50% to 150% in volume.[18] This swelling generates anions that are drawn to cations in the proteins of the mucous membrane, an interaction that enhances the connection between the oral tissues

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Clinical Implications
The antimicrobial activity of denture adhesives is important for denture wearers, as prolonged denture use may lead to *Candida*-associated denture stomatitis. Further research is needed to evaluate the current situation and explore ways to improve it.

and the denture, ultimately creating a retentive force that secures the denture to the oral mucosa through an interposed film.[2,3,8,11]

Early denture adhesives contained natural materials like plant rubbers (acacia, karaya, tragacanth, xanthan), but these had limitations such as poor retention, allergic reactions, and demineralization of the opposing dentition.[5] In response, manufacturers in the 1970s and 1980s introduced adhesive compositions with ingredients like methyl cellulose, sodium-carboxy methyl cellulose (CMC), and synthetic polymers (for example, polyvinyl methyl ether-maleic acid [PVM-MA]) for stronger adhesion.[2,5,8,11,19] Calcium and zinc salts were also added to improve retention,[11] and formulations often included antimicrobial agents, additives, colorants, flavorings, fillers, preservatives, and thickeners.[3,8,19]

Most available denture adhesives aim to prevent microbial growth[5,20–22] and may contain antifungal agents to help treat denture stomatitis by reducing irritation of the supporting tissues and aiding recovery.[23] To improve antimicrobial activity, substances such as sodium–magnesium–zinc (Na–Mg–Zn), calcium–zinc (Ca–Zn), calcium–sodium (Ca–Na), PVM–MA copolymers, methyl salicylate, polyethylene glycol (PEG), sodium tetraborate, sodium borate, hexachlorophene, propyl hydroxybenzoate, chlorophyll, glycerin triacetate, and ethanol have been added.[9,16,19,23–28]

Denture adhesives have been classified as nonsterile pharmaceuticals by the United States Food and Drug Administration.[6] The antimicrobial properties of denture adhesives have been investigated because of the variety of types and concerns that a thick adhesive layer may serve as a microbial reservoir, potentially leading to *Candida*-associated denture stomatitis (CADS).[9,13,14,29–31] Incorporating chitosan,[32] chlorhexidine,[33] and zinc oxide[31] into denture adhesives has been reported to have promising antifungal effects against *Candida albicans*, suggesting these agents may help prevent CADS, improve denture functionality and reduce oral irritation. However, there are conflicting studies on whether denture adhesives possess sufficient antimicrobial effects to reduce the growth of microorganisms,[7,12,26,34] and limited data on whether the long-term use of adhesives may affect the oral microflora.[16] Therefore, the purpose of this scoping review was to investigate and evaluate studies on the antimicrobial activity of denture adhesives and assess whether adding antimicrobial agents is beneficial and effective in reducing microbial growth. The research hypotheses were that denture adhesives possess antimicrobial properties and that the addition of antimicrobial agents in denture adhesives would be effective in treating CADS.

MATERIAL AND METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[35] were used for the review. Research questions were developed based on the study objectives using the participant, intervention, control, outcome (PICO) model (Table 1).[36,37] The questions included: Do complete or partial denture wearers benefit from the antimicrobial effects of using denture adhesives?; Do denture adhesives inherently possess antimicrobial properties?; Would the addition of further antimicrobial agents in denture adhesives be effective in reducing microbe growth?; What types of additional antimicrobial agents have been incorporated into denture adhesives and how were they incorporated?; and Are there any reports on the long-term effects of using denture adhesives? The electronic data search was conducted using 4 databases: Embase, Google Scholar, PubMed, and the Web of Science Core Collection (Table 2). The search included all articles in English in peer-reviewed journals up to October 2023. Additionally, a manual search was performed.

The results of the search were categorized using a reference management software program (EndNote X20; Clarivate). The inclusion and exclusion process, based on the 5 research questions, was carried out by 2 reviewers (S.A., N.Y.). Exclusion criteria were developed and applied, including topics unrelated to the antimicrobial properties of denture adhesives such as the

Table 1. PICO model

Patient, Population	Denture Wearers, Whether Complete or Partial, Who Use DAs, Especially Those With *Candida*-associated Denture Stomatitis.
Intervention (or Exposure)	Denture wearers using DAs with additional antimicrobial agents.
Comparison (or Control)	Regular DAs versus DAs with additional antimicrobial agents.
Outcome	DAs possess or include general antimicrobial agents to prevent growth of microorganisms. Despite this intention, it remains unclear whether incorporated antimicrobial agents are effective or if effects are caused by other ingredients.

DAs, denture adhesives; PICO, patient, population, intervention, comparison, outcome.

Table 2. Key search terms and number of records in database systems

Database	Accessed Date	Search Setting	Search Terms	No. of Articles
Embase	Oct 22, 2023	Broad search, no limit	"Denture adhesives" and antibacterials	0
			"Denture adhesives" and antifungals	38
			"Denture adhesives" and antimicrobials	0
Google Scholar	Oct 22, 2023	Anytime, sort by relevance, any type, not including patents and citations	"Denture adhesives" and antibacterials	677 (120)*
			"Denture adhesives" and antifungals	313 (100)*
			"Denture adhesives" and antimicrobials	641 (150)*
PubMed	Oct 22, 2023	Filters applied: Abstract, free full text, full text, sort by best match, 10 years	"Denture adhesives" and antibacterials	229 (50)*
			"Denture adhesives" and antifungals	19
			"Denture adhesives" and antimicrobials	389 (70)*
Web of Science Core Collection	Oct 23, 2023	Documents, all fields, basic search	"Denture adhesives" and antibacterials	0
			"Denture adhesives" and antifungals	20
			"Denture adhesives" and antimicrobials	30
Total				597

* indicates articles only considered applicable for review after reading titles and abstracts.

retention strength of adhesives, the physical properties of adhesives, dental adhesive systems, dental cements, luting agents, dental bonding agents, root canal cements, orthodontic adhesives, reviews, systematic reviews, updates, and theses.

RESULTS

A total of 597 articles were initially identified through the search process, with 12 results from the reference management software program categorized into 4 database groups under 3 headings based on the research terms (Table 2). After removing duplicates from each dataset, 160 references remained. Following another round of duplicate removal across the 4 databases, 72 articles were left for eligibility checking by reviewing titles and abstracts and applying the exclusion criteria (Fig. 1). Ultimately, 40 articles were selected for the scoping review, including three[11,38,39] identified through manual search. The information was evaluated by identifying author, country, year, adhesive type, composition, antimicrobial test methods, microorganisms, additional agents, and results, as detailed in Supplemental Table 1 (available online).

The characteristics of the selected articles, including the antimicrobial effectiveness of denture adhesives that contained additional antimicrobial agents and those without agents, comparisons of denture adhesives without antimicrobial agents, cytotoxicity test, test duration, pH test, and microorganisms involved are presented in Table 3. Over 40% of the articles (17 of 40) investigated the addition of antimicrobial agents to denture adhesives to enhance their effectiveness. The additional antimicrobial agents, their incorporation mechanisms, and methods are summarized in Table 4. These agents were categorized into 5 groups. The commercial antifungal agent group included amphotericin B, chlorhexidine, cydiodine, and nystatin, while the azole group included clotrimazole, fluconazole, and pyrazole. In the micro- or nanoparticle group, different particles were used, including miconazole nitrate microparticles, silver nanoparticles (AgNPs), zinc oxide particles (ZnO) and nanoparticles (ZnONPs), and zirconia nanoparticles (ZrO_2NPs). For the natural and organic materials group, 6 organic substances including chitosan, endophytic fungi *Aspergillus sp*. extract, antimicrobial lipids, organic olive oil, plant extracts, and probiotics were evaluated. The "others" group used surface pre-reacted glass ionomer (S-PRG) treatment. Overall, incorporating various additional antimicrobial agents into commercially available denture adhesives demonstrated consistent and improved antimicrobial effectiveness against oral microbiota pathogens. Eight articles were also identified that reported the antimicrobial effectiveness of denture adhesives that did not contain additional agents (Table 5). However, only 4 of these articles specified the compositions of the denture adhesives but reported that the main components associated with antimicrobial effects could be attributed to polyvinyl methyl ether-maleic (PVM-MA) copolymers, such as Ca–Zn PVM-MA copolymers, Ca–Na PVM-MA copolymers, Na–Mg–Zn copolymers, as well as sodium borate, chlorophyll, and glycerin triacetate. Furthermore, 11 articles were found that compared the antimicrobial effectiveness of commercially available denture adhesives that did not contain additional agents. Table 6 shows that many of these commercially available denture adhesives contained components such as Ca-Na PVM-MA, Na–Cu chlorophyllin, and polyethylene glycol (PEG). However, these additions had mixed results, with only some being effective. Cytotoxicity tests, as expected, also revealed variations based on the type of denture adhesive,[10,32,40,41] test duration,[11,42,43] and the concentration of antimicrobial agents[44] (Table 7).

DISCUSSION

Denture adhesives have been widely used for their functional benefits; however, their antimicrobial properties have not been extensively evaluated. Limited data exist on whether denture adhesives provide antimicrobial effects inherently because of their chemical composition or whether adding an antimicrobial agent is

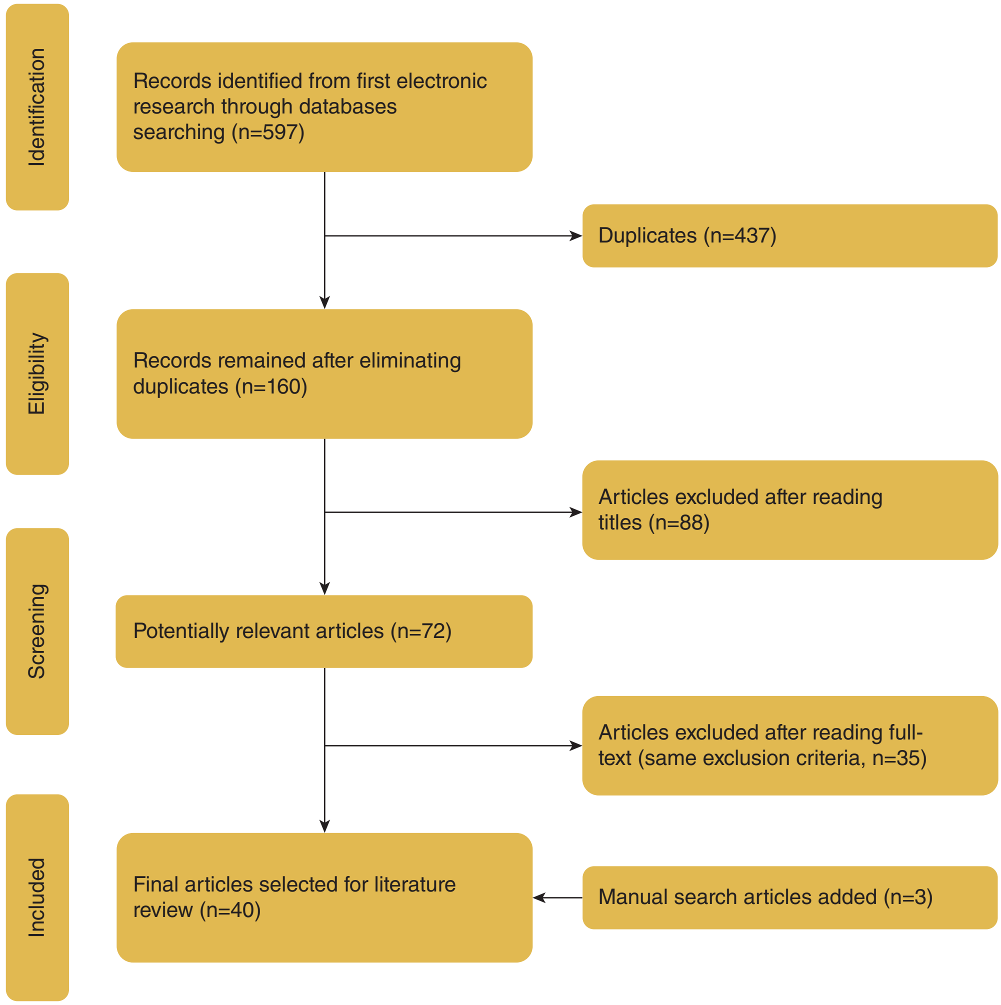

Figure 1. Inclusion and exclusion process.

Table 3. Characteristics of results of selected articles

Characteristics	No. of Reviewed Articles	References
Antimicrobial Effectiveness with Additional Antimicrobial Agents	17	10,15,18,24,27,29,31–34,42,44–48,56
Additional Antimicrobial Agents	17	10,15,18,24,27,29,31–34,42,44–48,56
Antimicrobial Effectiveness without Additional Antimicrobial Agents	8	12,16,26,28,38,39,49,50
Comparison of DAs without Antimicrobial Agents	11	7,9,13,23,50–55,57
Cytotoxicity Test	Brine shrimp eggs (1)	42
	Fibroblast cells (L–929 or NIH/3T3) (3)	10,11,41
	Human gingival (Epithelial or fibroblasts) cells (3)	32,43,44
	Macrophages (1)	40
Duration of Test	10–12 hrs (4)	9,24,27,45
	24 hrs (4)	32,38,53,56
	120 hrs (1)	28
	1 week (1)	18
	2 weeks (4)	7,13,33,55
	4–5 weeks (2)	15,47
	2 months (1)	16
pH Test	6	9,12,28,43,48,58
Microorganisms	*Candida albicans* and *Candida* spp. (30)	7,10,12,13,15,16,18,23,24,26–29,31–34,42,44–48,51–56,58
	Streptococcus mutans (8)	7,9,16,38,48–50,57
	Staphylococcus aureus (2)	16,51
	Others (7)	16,32,39,48,49,51,52

DAs, denture adhesives.

Table 4. Summary of additional antimicrobial agents

Classification	Additional Antimicrobial Agents	Incorporation Mechanism or Methods	References
Commercial Antimicrobial Agents	Amphotericin B	Solution form with DA gels Compounded directly to DA	Bates et al[29] Garaicoa et al[44]
	Chlorhexidine diacetate (CHDA)	Mixing with DAs and coated in 24-well plate	Matalon et al[33]
	Chlorhexidine dihydrochloride (CHDH)	Solution form with DA gels Compounded directly to DA	Bates et al[29] Garaicoa et al[44]
	Chlorhexidine gluconate (CHG)	Solution form with DA gels Compounded directly to DA	Bates et al[29] Garaicoa et al[44]
	Cydiodine	Not available	Zhao et al 2002[56]; Zhao et al 2004[43]
	Nystatin	Solution form with DA gels Compounded directly to DA Hot melting extrusion and film form	Bates et al[29] Garaicoa et al[44] Park et al[45]
Azole Group	Clotrimazole	Hot melting extrusion and film form	Park et al[45]
	Fluconazole	Solution form with DA gels Compounded directly to DA	Bates et al[29] Garaicoa et al[44]
	Pyrazole	Impregnation method was used for incorporating pyrazole in tape. Imbition method was used antifungal agent in powder and cream	de Oliveria et al[10]
Micro- or nanoparticles	Miconazole nitrate microparticles	Microparticles mixing with DAs, mixing active water-soluble polymers and base components	Cartagena et al[42]
	Silver nanoparticles	Mixing with DA powder	Peralta et al[27]
	Zinc-oxide (ZnO) particles and nanoparticles	ZnO and DA poured into culture tube, or broth media mixed with DA compound	Jamshidy and Jafari[31]
	Zirconia particles and nanoparticles	DA dissolved by heating in culture medium	Mahmudi et al[46]
Natural and Organic Materials	Chitosan (water soluble chitosan and acid soluble chitosan)	Mixing as pure gel with DAs	Namangkalakul et al[32]
	Endophytic fungi *Aspergillus sp.* extract	Mixing with DA and *Aspergillus sp.*	Fadriyanti et al[34]
	Monoglyceride monocaprin (antimicrobial lipids)	Not available	Holbrook et al[47]
	Organic extra olive oil	Mixing with DAs cream	Azevedo et al[18]
	Plant extracts: Equisetaceae (*Equisetum giganteum*), Lythraceae (*Punica granatum*)	Mixing with DAs powder	Almeida et al[24]
	Probiotics: *Lactobacillus acidophilus*, *Lactobacillus rhammosus*, *Bifidobacterium bifidum*	Adding probiotic powder to DA powder	Chhabra et al[15]
Others	Surface pre-reacted glass-ionomer (S-PRG)	Mixing with DA in different concentration	Hatano et al[48]

DAs, denture adhesives.

effective in reducing microbial growth. Additionally, the long-term impact of denture adhesives on the oral microflora and CADS remains unclear. Consequently, many studies have investigated whether incorporating additional antimicrobial agents into denture adhesives is beneficial and effective in reducing microbial growth (Table 4). The research hypotheses that denture adhesives possess antimicrobial properties and that the addition of antimicrobial agents to denture adhesives would be effective in treating CADS were partially accepted, as some denture adhesives inherently possess antimicrobial properties and because adding further

Table 5. Antimicrobial effectiveness without additional antimicrobial agents

Author	Brand and Type of Adhesives	Possible Antimicrobial Components or Agents
He et al[38]	Fixodent cream	Ca–Zn salt of PVM-MA, CMC, SiO_2, mineral oil, petrolatum, color.
Ignar et al[39]	Super PoliGrip Original	Not available
Makihira et al[12]	Cushion Collect, Collect Soft A, Linden, Liodent Pink, Tafu Grip, and Tafu Grip Hadairo	Not available
Ozkan et al[16]	Kukident	Not available
Polyzois et al[49]	Corega Ultra, Fixodent Pro Original, and Biotene Denture Grip	Na–Mg–Zn, Ca–Zn PVM–MA copolymers for Corega Ultra, Fixodent Pro Original and lactoperoxidase, lysozyme and lactoferrin (LP3 enzyme–protein system) for Biotene Denture Grip.
Rajaiah et al[50]	Fixodent Complete and Fixodent Fresh	Not available
Rajaram and Manoj[28]	Secure powder, cream, and strip	Powder: Sodium CMC, polyvinyl acetate, silicon dioxide, and sodium borate. Cream: Sodium CMC, polyvinyl acetate, petrolatum, chlorophyll, cationic resin, denatured alcohol and hydroxypropyl cellulose. Strip: Polyvinyl acetate, sodium CMC, glycerin triacetate, and petrolatum.
Sampaio-Maia et al[26]	Corega cream, Kukident cream, Novafix cream, Polident cream, Protefix cream, Steradent cream, Aderyn powder, Corega ultra powder, Protefix powder, and Corega strip	Na–Mg–Zn PVM–MA copolymers, Ca–Zn PVM–MA copolymers, Ca–Na salts of copolymer PVM-MA, p-hydroxybenzoic acid and methyl ester (preservatives), PEG-90M, propylparaben (antiseptics), and Zn.

CMC, carboxymethylcellulose; PEG, polyethylene glycol; PVM-MA, polyvinyl methyl ether-maleic acid.

Table 6. Comparison of denture adhesives without antimicrobial agents

Author	Brand and Type of Adhesives	Antimicrobial Agents in their Compositions	Microorganisms	Results
Barnes et al[57]	Fixodent Hygiene and Poligrip Total Care	Not available	*S. mutans*	Log inhibition of CFU/mL. Poligrip (approx. 1.3 Log_{10}) < Fixodent (approx. 2.9 Log_{10})
Chen et al[9]	Polident cream, Protefix cream, and Protefix powder	Ca–Na salts of copolymer PVM-MA and Na–Cu chlorophyllin	*S. mutans*	Simple sigmoid growth showed that none of tested DAs significantly affected *S. mutans*. No exact data available.
Costa et al[51]	Ultra Corega cream, Corega strip, and Ultra Corega powder	Ca–Na salts of copolymer PVM-MA and PEG	*C. albicans, Pseudomonas aeruginosa,* and *S. aureus*	All variations of DAs contributed to increased biofilm formation across 3 strains. Although they contained Ca-Na salts of PVM-MA and PEG as antimicrobial components, their effectiveness seemed insufficient to decrease biofilm.
Darwish et al[54]	Corega Ultra powder, Protefix cream, Corega super cream, and OlivaFix cream	Ca–Na salts of copolymer PVM-MA and p-hydroxybenzoic acid and methyl ester (preservatives)	*C. albicans*	Higher mean CFU counts per specimen in adhesive-exposed groups compared to non-exposed groups for both UDMA and PMMA resins, versus control groups were shown.
de Oliveira Junior et al[52]	Ultra Corega cream and Corega strip	Ca–Na salts of copolymer PVM-MA and PEG	*C. albicans* and *Lactobacillus casei*	*C. albicans* biofilm was greater with strip adhesives due to different solubility mechanisms than cream adhesives. Despite previous findings, this study did not observe *C. albicans* inhibition by Lactobacillus strain examined (*L. casei*).
Dewi et al[23]	DA cream (GSK) and Fittydent	Ca–Na salts of copolymer PVM-MA and prophyl hydroxybenzoate	*C. albicans*	DAs did not inhibit growth of *C. albicans* with disc diffusion method (no transparent area).
Kim et al[55]	Poly Grip Free cream	Not available	*C. albicans*	There was no substantial reduction of *C. albicans* in total viable counts using Poly Grip Free for 14 days.
Leite et al[7]	Ultra Corega cream	Not available	*Candida* spp., *S. mutans*	There was no impact on CFU of microorganisms, neither increase nor decrease in biofilm formation on internal surface of complete dentures and palatal mucosa of denture wearers for 15 days.
Nomura et al[53]	New Poligrip Sa cream, Poligrip powder Fa, and Toughgrip Pink A.	Ca–Na salts of copolymer PVM-MA and ethanol	*C. albicans*	Tested DAs accelerated growth of *C. albicans*. Hyphal form of *C. albicans* (indicative of inflammation on oral mucosa becoming pathogenic) in cream and powder type adhesives at 6 and 12 hrs.
Oliveira et al[13]	Ultra Corega adhesive tape	Not available	*Candida* species	Use of DA did not lead to statistically significant increase or decrease in absolute count of *Candida* and other yeasts in oral cavity of individuals, suggesting need for further study involving different products.
Rajaiah et al[50]	Fixodent Complete and Fixodent Fresh	Not available	*S. mutans*	Mean log reduction. Fixodent Fresh (1.25 Log_{10}) < Fixodent Complete (> 4.03 Log_{10})

CFU, colony forming unit; DAs, denture adhesives; PEG, polyethylene glycol; PMMA, polymethyl methacrylate; PVM-MA, polyvinyl methyl ether-maleic acid; UDMA, urethane dimethacrylate.

Table 7. Summary of cytotoxicity test

Author	Microorganisms	Additional Antimicrobial Agents	Results
Agarwal et al[40]	Macrophages	Not available	Fixon powder exhibited highest toxicity, followed by Dentiro powder and Metrodent powder, with Fixon cream being least cytotoxic.
Al et al[41]	L−929 fibroblast cells	Please see Supplemental Table 1	Blend-a-dent cream showed significant cytotoxicity.
de Gomes et al[11]	L−929 fibroblast cells	Not available	Most exhibited some level of cytotoxicity after 12 hrs.
de Oliveira et al[10]	NIH/3T3 fibroblast cells	Not available	Both powder and cream types showed similar cytotoxicity to control, while tape type did not exhibit cytotoxicity.
Cartagena et al[42]	Brine shrimp eggs	Miconazole nitrate	Minimal to no toxicity after 24 and 48 hrs
Garaicoa et al[44]	Human gingival epithelial keratinocyte cell lines	AmB, chlorhexidine dihydrochloride, chlorhexidine gluconate, fluconazole, and nystatin	Not cytotoxic to cell line
Namangkalakul et al[32]	Human gingival fibroblasts	High-molecular-weight water-soluble chitosan	No significant difference in cell viability
Zhao et al[43]	Human gingival fibroblasts	Cydiodine	Significant cytotoxicity after 2 days, but not after 3 and 4 days, indicating slight cytotoxicity over time.

AmB, amphotericin B.

antimicrobial agents to denture adhesives was effective in treating CADS.

Commercially available antifungal agents, including amphotericin B, chlorhexidine, cydiodine, and nystatin, have been incorporated into denture adhesives using various mixing methods. All demonstrated consistent antimicrobial effectiveness against oral microbiota pathogens like *C. albicans*, which may reduce CADS.[29,44] Chlorhexidine has been used in different forms: chlorhexidine diacetate (CHDA),[33] chlorhexidine dihydrochloride (CHDH),[29,44] chlorhexidine gluconate (CHG),[29,44] all of which could treat CADS. Specifically, 7.7 wt% powdered CHDA was added to 3 denture adhesives (Corega, Kukident, and Protefix) and was reported to inhibit *C. albicans* growth, although the effectiveness declined after 24 hours because of material decomposition and dissolution.[33] This time-span may be acceptable, as denture adhesives typically remain effective for only 2 to 4 hours in the oral cavity, losing 30% to 50% of their functionality within 6 hours because of exposure to saliva and mastication forces.[24] For optimal oral and denture hygiene, denture adhesives should be replaced or reapplied after each meal to assist in the mechanical cleaning of both the internal and external denture surfaces.[24]

The effectiveness of the azole group, common antifungal agents which include clotrimazole, fluconazole, and pyrazole, has been evaluated,[10,29,44,45] demonstrating antifungal effects against *C. albicans*. The widely accepted theory for their antimicrobial activity is that they inhibit the synthesis of ergosterol in pathogenic fungi, leading to the loss of intracellular constituents.[10] Although various incorporation methods were identified in the review, the direct mixing of anti-agents with denture adhesives was most commonly used, either in solution form or compounded with the denture adhesive.[29,44] Notably, an antifungal denture adhesive film system was developed by using hot melt extrusion technology. The findings not only demonstrated antifungal effects against *C. albicans* but also showed potential for treating oral or pharyngeal candidiasis through controlled release.[45]

Several micro- or nanoparticles (NPs) have been used to fabricate antimicrobial denture adhesives, all exhibiting significant antifungal activity.[27,31,42,46] These particles had the added advantage of serving as effective drug delivery systems to inhibit microorganisms in denture bases, liners, and tissue conditioners.[42] Specifically, zinc oxide particles and NPs[31] and zirconia NPs[46] were evaluated, and the nanoparticle forms were more effective against fungal pathogens than their larger counterparts, suggesting that nanoparticles have greater efficacy because of their high surface-to-volume ratio, which enhances contact with fungi and increases their antimicrobial activity compared with larger particles.[31,46]

Researchers have increasingly focused on natural and organic materials because of the growing global prevalence of antifungal drug resistance.[24] Frequent use of antifungal drugs can promote resistance by triggering the overexpression of drug efflux pumps or causing mutations in target enzymes.[32] As a result, several studies in this review investigated the antimicrobial effects of denture adhesives containing natural and organic materials.[15,18,24,32,34,47] Among them, various types of chitosan were used in antifungal denture adhesives, with high-molecular-weight, water-soluble chitosan (HMWC) showing particular promise in reducing *C. albicans* adherence to coated denture base resin. Additionally, HMWC demonstrated no cytotoxicity to gingival fibroblast cells and could be used to prevent denture stomatitis.[32] Interestingly, when 3 cream forms of denture adhesives were mixed with 30% olive oil, the increased inhibition of *C. albicans* growth after 7 days compared with the control group was reported. The prolonged antifungal effects (up to 7 days) may be because of the high concentration of olive oil, which contributed to longer-lasting adhesion and antimicrobial properties.[18] Olive oil's phenolic compounds also offer anti-inflammatory benefits. The authors noted that in vitro results may not always reflect in vivo conditions, as factors like saliva composition, flow, and pH can affect *C. albicans* growth.[18] In the other group, surface prereacted glass-ionomer (S-PRG) fillers in denture adhesives demonstrated excellent antimicrobial activity against oral pathogens, which may release ions like fluoride, strontium, sodium, aluminum, boric acid, and silicic acid. These ions have been reported to provide antimicrobial effects, tooth remineralization, and acid buffering.[48]

To assess the inherent antimicrobial properties of denture adhesives, this review evaluated the effectiveness of denture adhesives that did not contain additional agents (Table 5). Of the 8 articles reviewed, 7 reported that denture adhesives without added antimicrobial agents appeared to possess inherent antimicrobial effects against oral pathogens,[12,16,26,28,38,39,49,50] but only 4 articles provided details of the denture adhesive composition.[26,28,38,49] Among them, PVM-MA copolymers were most commonly used, along with additional components such as Ca–Na, Ca–Zn, Na–Mg–Zn copolymers, PEG-90M, antiseptic agents, sodium borate, chlorophyll, and glycerin triacetate. One of the components was the LP3 enzyme-protein system which contains lactoperoxidase, lysozyme, and lactoferrin.[49] Specifically, lysozyme, a natural antimicrobial enzyme, weakens bacterial cell walls, causing lysis, clumps bacteria to prevent adhesion to soft tissues, and triggers enzymes that destroy bacteria. Particularly, 1 study[16] reported no significant difference in microflora counts between patients using commercial denture adhesives and those not using them. This in vivo study tested 30 denture-wearing patients using denture adhesives for up to 2 months despite denture adhesives generally providing adhesion for only 8 to 16 hours.[4,5,21,22] The authors concluded that long-term denture adhesive use had no substantial impact on the microflora, though this finding remains debatable.[16]

Inconsistent results were found when comparing the antimicrobial effectiveness of commercially available denture adhesives without additional agents (Table 6). Of the 11 studies, most reported no antimicrobial effects from the tested products. Five studies investigated various types of denture adhesives in cream, powder, strip, and cushion forms.[9,23,51–53] Despite containing antimicrobial agents like Ca–Na salts of the copolymer PVM-MA, Na–Cu chlorophyllin, a mixture of propyl hydroxybenzoate and sodium-CMC, PEG, and ethanol, these denture adhesives showed no significant antimicrobial effects.[9,23,51–53] The studies suggested that variations in denture adhesive types, bacterial strains, microbial population size, composition of active components, concentration of antimicrobial agents, and experimental methods may have influenced the results.[9,23] The strip form, in particular, appeared to have higher biofilm formation associated with differences in solubility mechanisms between the strip and cream forms.[52] Therefore, caution regarding the prolonged use of denture adhesives was suggested,[53] along with daily cleaning and the removal of adhesives for oral hygiene.[51] Biofilm formation on dentures and palatal mucosa[7] denture base resins,[54] and saliva samples[13,55] was evaluated, and no indication of antimicrobial effects was found. Denture adhesives have been reported to be safe for short-term use only if dentures are properly cleaned, as adhesives tend to accumulate on denture surfaces,[55] which could worsen inflammation, CADS, and halitosis.[7] Denture adhesives have been recommended for use as a complementary treatment, not as a stand-alone option.[49] Overall, many commercially available denture adhesives claim to be antimicrobial and contain antimicrobial components; however, this review revealed mixed results, with some being effective and others not.

The scoping review identified 8 articles examining the cytotoxicity of denture adhesives. Leachable components in denture adhesives can be ingested and absorbed by the oral mucosa, potentially harming tissues.[40] Overall, the review revealed mixed results in cytotoxicity tests (Table 7), with variations based on the type of denture adhesive,[10,32,40,41] test duration,[11,42,43] and concentration of antimicrobial agents.[44] While some products demonstrated significant cytotoxicity, identifying the specific components responsible for these effects remains challenging,[41] and, in some situations, the cytotoxicity was minimal or absent.[44] Therefore, when using denture adhesives—whether or not they are combined with antimicrobial agents—consideration should be given to the type, duration, and concentration of the application.

CONCLUSIONS

Based on the findings of this scoping review, the following conclusions were drawn:

1. Whether commercially available denture adhesives inherently possess antimicrobial effects remains unclear.
2. While many studies show that denture adhesives exhibit antifungal or antibacterial effects, whether these effects are associated with the included antimicrobial agents or components or other ingredients is unclear.

3. Additionally, results were variable: some denture adhesives showed antimicrobial effects, while others did not, despite having similar compositions.
4. Incorporating different or new antimicrobial agents into denture adhesives could reduce biofilm formation and inhibit oral microorganism growth in denture wearers.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2024.11.007.

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