

Original article

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The Effects of *Ribes Nigrum* L. Extract and Commercial Denture Cleansers on Mechanical and Wetting Properties of Poly(Methylmethacrylate) and *Candida Albicans* Adhesion: An *In Vitro* Study

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This study evaluated an extract from *Ribes nigrum* L. (black current) berries as a denture cleanser in comparison with commercial cleansers (Corega and Protefix), focusing on the mechanical and wetting properties of denture base resin and *Candida albicans* adhesion. PMMA samples were exposed to nine different immersion protocols. For adhesion assessment, samples were incubated with a *C. albicans* suspension for 4 h and subsequently treated with the extract or commercial cleansers. *Candida* adhesion was quantified using the XTT reduction assay. *R. nigrum* extract reduced *C. albicans* adhesion by approximately 50% while preserving PMMA mechanical properties, including hardness and Young's modulus, regardless of the immersion protocol. All tested solutions decreased the water contact angle of PMMA surfaces. These findings suggest that *R. nigrum* extract may serve as a promising natural denture cleanser, capable of reducing *C. albicans* adhesion while preserving the mechanical integrity of PMMA more effectively than conventional cleansers.

Key words: Denture Bases Resin, Denture Cleansers, *Ribes nigrum* L., Surface Properties, *Candida albicans*

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Efekti ekstrakta *Ribes nigrum* L. i komercijalnih sredstava za čišćenje proteza na mehanička svojstva i svojstva kvašenja poli(metilmetakrilata) i adheziju *Candida albicans*: In vitro studija

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U ovoj studiji ispitivan je prirodni ekstrakt dobijen iz podova *Ribes nigrum* L. (crna ribizla) kao potencijalno sredstvo za čišćenje zubnih proteza u poređenju sa komercijalnim preparatima (Corega i Protefix), sa fokusom na mehanička svojstva i svojstva kvašenja baze ploče proteza, kao i na adheziju gljive *Candida albicans*. PMMA uzorci bili su izloženi devet različitih režima potapanja. Za procenu adhezije, uzorci su inkubirani u suspenziji *C. albicans* tokom 4 h, nakon čega su tretirani ekstraktom ili komercijalnim sredstvima za čišćenje. Adhezija gljive kvantifikovana je primenom XTT testa. Ekstrakt *R. nigrum* smanjio je adheziju *C. albicans* za približno 50%, uz očuvanje mehaničkih svojstava PMMA, uključujući tvrdoću i Jangov modul elastičnosti, nezavisno od primenjenog režima potapanja. Svi ispitivani rastvori smanjili su vodeni kontaktni ugao na površini PMMA. Dobijeni rezultati ukazuju da

ekstrakt *R. nigrum* predstavlja perspektivno prirodno sredstvo za održavanje higijene proteza, sposobno da smanji adheziju *C. albicans* uz bolje očuvanje mehaničkog integriteta PMMA u poređenju sa konvencionalnim sredstvima za čišćenje.

Ključne reči: Baze ploče proteza, Sredstva za čišćenje proteza, *Ribes nigrum* L., Površinska svojstva, *Candida albicans*

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Introduction

Dentures, typically made from poly (methylmethacrylate) (PMMA), are widely used for the rehabilitation of edentulous patients; however, they are highly susceptible to microbial contamination¹. Denture wearing is frequently associated with oral candidiasis due to microbial colonization and penetration into denture pores. Therefore, adequate denture hygiene requires maintaining physical, chemical, and biological cleanliness^{2,3}.

Mechanical cleaning methods, such as brushing, are often insufficient and may cause surface wear of denture materials⁴. Consequently, chemical cleansers are commonly used. These products usually contain aggressive compounds, including chlorine- or peroxide-based agents³, which exhibit antimicrobial activity⁵ but may simultaneously induce degradation of PMMA. Such degradation can adversely affect mechanical properties^{6,7} and increase surface roughness, thereby promoting microbial adhesion and plaque accumulation⁸⁻¹⁴. Among oral pathogens, *Candida albicans* is the microorganism most frequently associated with denture surfaces and denture stomatitis^{8,15,16}.

An ideal denture cleanser should effectively eliminate microorganisms without compromising the surface morphology or mechanical properties of the denture material¹. For this reason, increasing attention has been directed toward natural antimicrobial compounds, including herbal extracts^{2,17-20}. Among herbal extracts, black currants (*Ribes nigrum* L.) are known for their antioxidative, antimicrobial, cytoprotective, and anti-inflammatory properties, mainly attributed to the presence of polyphenolic compounds, particularly anthocyanins and flavonols.^{21,22} Based on these properties, we hypothesized that *R. nigrum* extract could reduce *C. albicans* adhesion to PMMA without adversely affecting its mechanical and wetting surface properties.

Aim

The aims of this study were to evaluate: (1) the effects of *R. nigrum* extract on the mechanical and wetting properties of PMMA compared with commercial denture cleansers, and (2) its potential to reduce *C. albicans* adhesion to PMMA surfaces.

Methods

Samples preparation and immersion procedure

PMMA samples (n=40) were prepared from heat-polymerized acrylic resin (Triplex Hot, Ivoclar Vivadent, Liechtenstein) in the form of rectangular plates (20 × 20 × 3 mm). Polymerization was performed in a metal flask using boiling water for 45 min. After polishing, the samples were immersed in distilled water for 48 h to eliminate residual monomers and subsequently sterilized under a UV-C lamp for 15 min.

Three denture cleansers were evaluated: *R. nigrum* extract, Corega (Block Drug Company, Jersey City, NJ, USA), and Protefix (Queisser Pharma, Flensburg, Germany). The *R. nigrum* extract was prepared from berries of the Ben Sarek variety, grown and collected at Mislodjin (the experimental field of the Faculty of Agriculture, University of Belgrade), using 70% methanol (1:10, w/v) under continuous stirring for 24 h. After complete evaporation of the extraction solvent using a vacuum evaporator, the crude extract was obtained and stored at 4°C until use. A 10% (w/v) water solution of the extract was used for all experiments. The phytochemical composition of this extract has been previously characterized by Miladinović et al. ²¹, who reported a high content of polyphenolic compounds, particularly anthocyanins and flavonols, including delphinidin-3-O-rutinoside, cyanidin-3-O-rutinoside, delphinidin-3-O-glucoside, cyanidin-3-O-glucoside, myricetin, quercetin, and kaempferol. Commercial cleansers were prepared according to the manufacturers' instructions by dissolving one tablet in 200 mL of distilled water.

PMMA samples were exposed to nine different immersion conditions (Table 1): air (45 h), distilled water (45 h), artificial saliva (45 h), cleanser solutions alone (45 h), or alternating immersion in cleanser and water/saliva (5 h cleanser, 10 h water/saliva, 10 h cleanser, and 20 h water/saliva).

Table 1. Exposure time of the PMMA samples to different conditions: air, water, saliva, cleansers (Corega, Protefix, *R. nigrum*) for 45h, and alternately immersion in water or saliva and one of the 3 studied cleansers (Corega+water, Protefix+water, *R. nigrum*+water)

Exposure time				
Air	45h			
Water	45h			
Saliva	45h			
Corega	45h			
Corega+water	Corega	Water	Corega	Water
	5h	10h	10h	20h
Corega+saliva	Corega	Saliva	Corega	Saliva
	5h	10h	10h	20h
Protefix	45h			
Protefix+water	Protefix	Water	Protefix	Water
	5h	10h	10h	20h
Protefix +saliva	Protefix	Saliva	Protefix	Saliva
	5h	10h	10h	20h
<i>R. nigrum</i>	45h			
<i>R. nigrum</i> +water	<i>R. nigrum</i>	Water	<i>R. nigrum</i>	Water
	5h	10h	10h	20h
<i>R. nigrum</i> +saliva	<i>R. nigrum</i>	Saliva	<i>R. nigrum</i>	Saliva
	5h	10h	10h	20h

Characterization of mechanical properties

Mechanical properties were evaluated by nanoindentation using a Nano Indenter G200 system (Keysight/Agilent Technologies, USA) equipped with a Berkovich diamond tip. Measurements were performed under a maximum load of 10 mN. Calibration was carried out using fused silica as a reference material. Individual indents were positioned 25 μm apart. The loading time was 15 s, followed by a peak hold time of 10 s. Three indentations were performed for each specimen, and the mean value was subsequently calculated.

Characterization of wetting properties

The water contact angle was measured using a Drop Shape Analyzer DSA25B (Kruss GmbH, Germany) by the sessile drop method with Young–Laplace fitting. Droplet volume was maintained below 1 μL . Three droplets were analyzed per sample, with 30 measurements recorded for each droplet at intervals of 0.3 s.

Anticandida activity

Candida albicans ATCC 90028 was used in this study. The inoculum (10^6 cells/mL) was prepared in RPMI 1640 medium. PMMA samples were incubated with 400 μL of the inoculum for 4 h at 37°C to allow fungal adhesion. Following incubation, samples were washed to remove non-adherent cells and subsequently treated with 400 μL of the tested cleansers or *R. nigrum* extract (100 mg/mL). The concentration of 100 mg/mL was selected to ensure adequate exposure of adhered *C. albicans* cells to the bioactive compounds present in the extract during the treatment period and to evaluate its effect on fungal adhesion under conditions relevant to denture cleansing applications. Control samples were treated with distilled water.

Adhered *C. albicans* cells were quantified using the XTT reduction assay. XTT/menadione solution (final menadione concentration: 1 μM) was added to each sample, followed by incubation for 2 h at 37°C in the dark. Absorbance was measured at 490 nm. Results are reported as the mean of four experimental repetitions per group.

Statistical analysis

Data are presented as mean \pm standard deviation (SD). Normality was assessed using the Shapiro–Wilk test. Statistical analysis was performed using one-way ANOVA followed by Tukey’s post hoc test, with statistical significance set at $p < 0.05$. Analyses were conducted using SPSS software version 20.0.

Results

Mechanical properties

Young's modulus values of PMMA samples exposed to different immersion conditions are presented in Figure 1. Samples immersed in Corega and Protefix showed significantly lower Young's modulus values compared with the control groups (air and water immersion) ($p < 0.05$), with the exception of the Protefix + saliva condition.

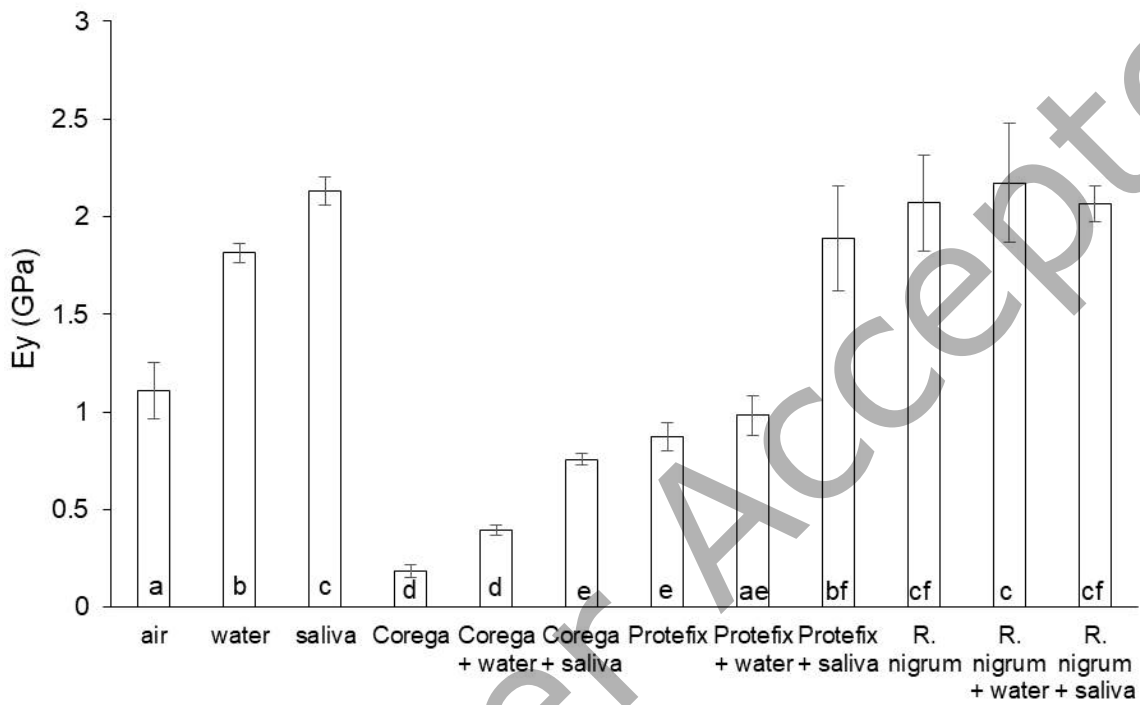


Figure 1. Young's modulus obtained by nanoindentation of PMMA samples exposed to different condition of the samples exposed to air (AIR), water (W), saliva (S), Corega (C), Protefix (P), *Ribes (R) Nigrum*. Values represent means \pm standard deviation. Bars indicate the mean values and vertical lines standard deviations. Different letters in the columns show significant differences among varieties (Tukey's test, $p < 0.05$).

Hardness results are shown in Figure 2. Both commercial cleansers significantly decreased PMMA hardness compared with the air and water control groups ($p < 0.05$), except for the Protefix + saliva condition. Samples treated with *R. nigrum* extract alone or in combination with water exhibited significantly higher hardness values than the air and water controls.

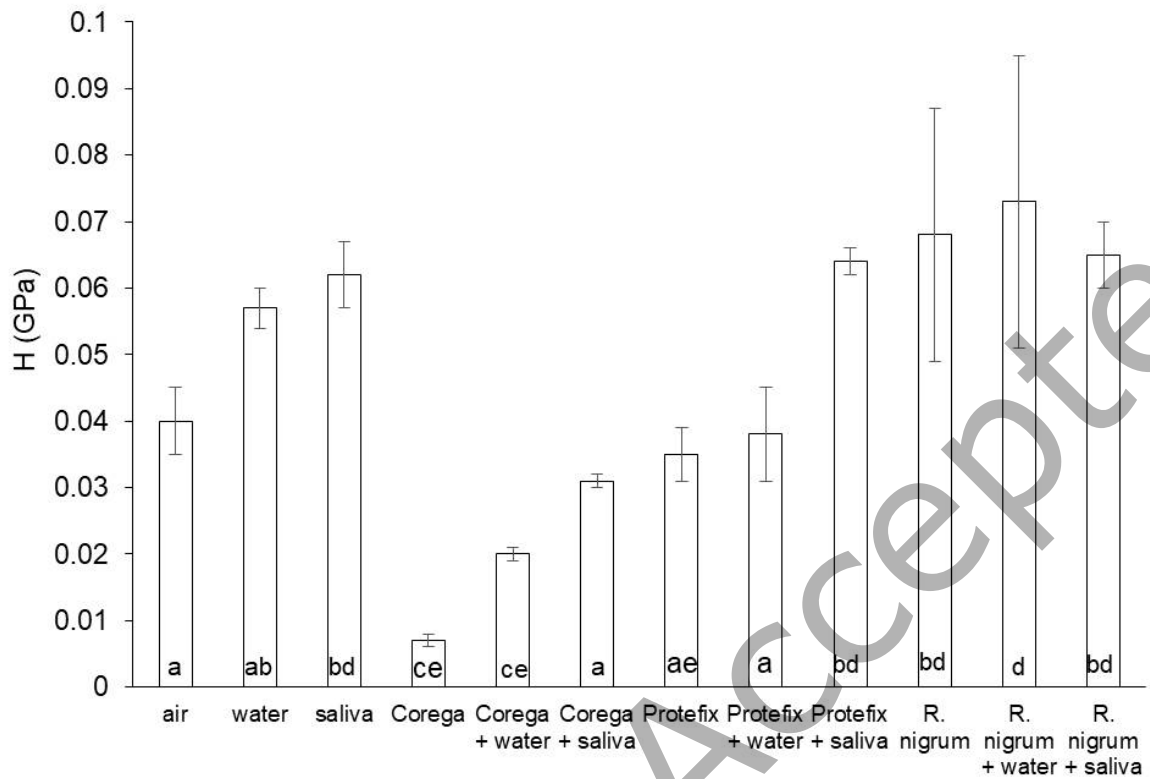


Figure 2. Hardness obtained by nanoindentation of PMMA samples exposed to different condition of the air (AIR), water (W), saliva (S), Corega (C), Protefix (P), *Ribes (R) Nigrum*. Values represent means \pm standard deviation. Bars indicate the mean values and vertical lines standard deviations. Different letters in the columns show significant differences among varieties (Tukey's test, $p < 0.05$).

Wetting properties

Water contact angle measurements are presented in Figure 3. All immersion protocols resulted in a significant decrease in the water contact angle of PMMA surfaces compared with the control conditions. The greatest reduction was observed after immersion in *R. nigrum* extract alone (13.26°) and in combination with saliva.

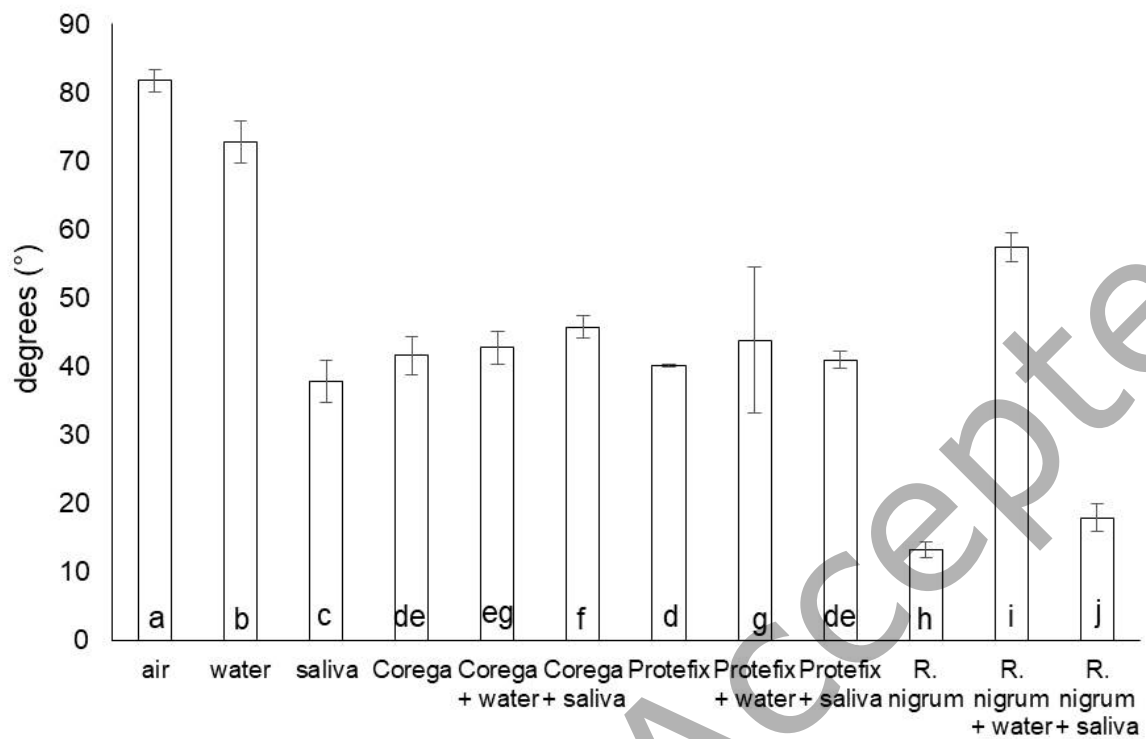


Figure 3. Water contact angle of PMMA samples exposed to different condition of the air (AIR), water (W), saliva (S), Corega (C), Protefix (P), *Ribes (R) Nigrum*. Values represent means \pm standard deviation. Bars indicate the mean values and vertical lines standard deviations. Different letters in the columns show significant differences among varieties (Tukey's test, $p < 0.05$).

Anticandida activity

The anticandidal activity of the tested cleansers and *R. nigrum* extract is presented in Figure 4. Treatment with *R. nigrum* extract reduced *C. albicans* adhesion to PMMA surfaces by more than 50% compared with the control group. Commercial denture cleansers (Corega and Protefix) also demonstrated anticandidal activity, with effects comparable to those observed for the *R. nigrum* extract.

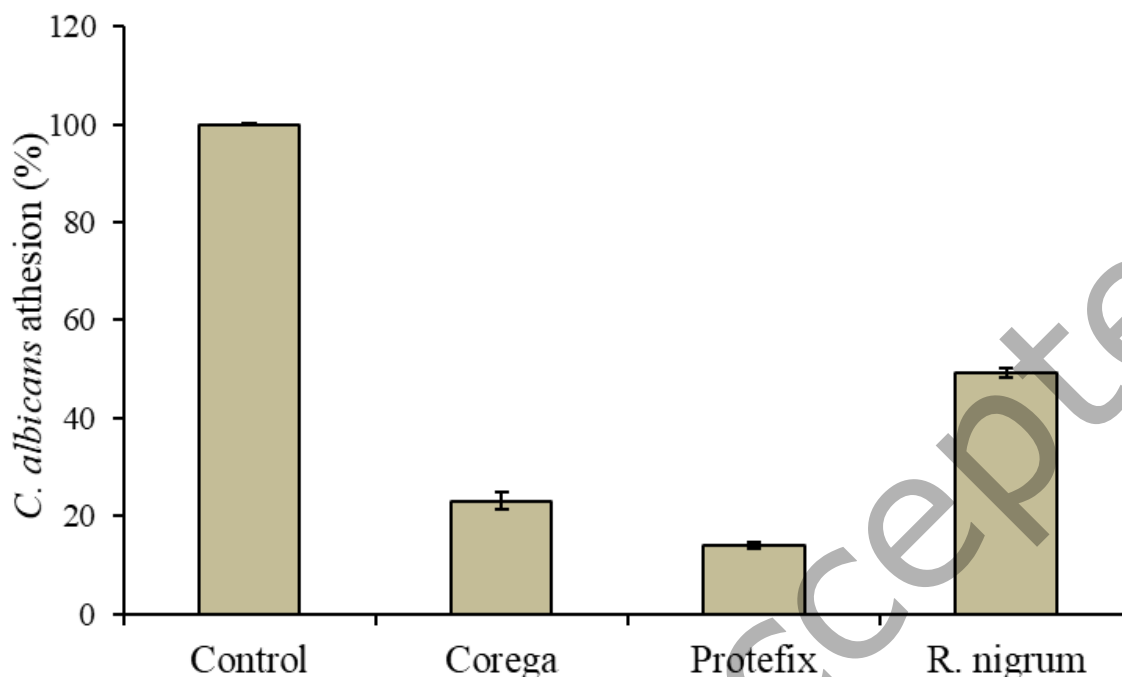


Figure 4. *C. albicans* adhesion (%) after immersion in commercial dental cleanser (Corega and Protefix), and *R. nigrum* extract, compared to control (samples immersed in water), determined by measuring *C. albicans* metabolic activity by XTT reduction assay.

Discussion

Denture hygiene is essential because microbial retention on denture surfaces promotes biofilm formation and may lead to oral mucosal infections²³. Among oral pathogens, *C. albicans* is the microorganism most commonly associated with denture-related infections and denture stomatitis^{8,15,16}. Therefore, the development of denture cleansers capable of reducing microbial adhesion without compromising denture material properties remains an important challenge.

R. nigrum berries are rich in biologically active compounds, including polyphenols, anthocyanins, flavonols, proanthocyanidins, and vitamin C^{21,22,24}. Previous studies demonstrated pronounced anticandidal activity of black currant extracts against planktonic *Candida* cells^{21,25,26}. The present study extends these findings by demonstrating, for the first time, that *R. nigrum* extract can significantly reduce *C. albicans* adhesion to PMMA surfaces while preserving the mechanical properties of the material.

Commercial denture cleansers, including Corega and Protefix, are mainly based on alkaline peroxide systems. Corega additionally contains tetraacetylenediamine (TAED), a peroxide activator, whereas

Protefix contains sodium lauryl sulfate^{11,29}. These compounds generate reactive oxygen species that contribute to antimicrobial activity but may simultaneously induce oxidative degradation of PMMA^{30,31}. Such degradation may adversely affect the mechanical integrity of acrylic denture materials. In agreement with previous studies^{6,11,12,27,34}, our results demonstrated reduced hardness and Young's modulus values after exposure to commercial cleansers. In contrast, *R. nigrum* extract preserved PMMA mechanical properties regardless of the immersion protocol, suggesting that its antifungal activity may primarily result from surface interactions rather than oxidative degradation mechanisms.

Prior to immersion experiments, PMMA samples were stored in distilled water for 48 h to eliminate residual monomers, which are known to act as plasticizers and negatively affect mechanical properties³². Water absorption by PMMA may also influence material behavior through plasticization effects^{33,34}. In the present study, air-exposed samples showed lower hardness and Young's modulus values than water-immersed samples, which is consistent with previously reported findings³. Furthermore, immersion in saliva resulted in increased mechanical property values compared with air and water immersion.

All tested solutions reduced the water contact angle of PMMA surfaces, indicating increased surface wettability. The most pronounced decrease was observed after immersion in *R. nigrum* extract alone and in combination with saliva. Changes in surface wettability may influence microbial adhesion and biofilm formation, since hydrophobic interactions play an important role in *Candida* attachment to acrylic surfaces^{38,39}.

Previous studies²¹ reported strong anticandidal activity of black currant extracts, with MIC and MBC values of 3.125 and 12.5 mg/mL, respectively, for the 70% methanolic extract of the Ben Sarek variety. In the present study, *R. nigrum* extract reduced *C. albicans* adhesion to PMMA surfaces by more than 50%. Comparable anticandidal effects were observed for Corega and Protefix, although variations in experimental methodologies among studies complicate direct comparisons^{14,35,40-43}. Importantly, unlike commercial cleansers, *R. nigrum* extract achieved this effect without compromising PMMA mechanical integrity, suggesting potential advantages for long-term denture maintenance⁴⁴.

Several limitations of this study should be acknowledged. Long-term effects of *R. nigrum* extract on PMMA color stability, water sorption, and solubility were not evaluated⁴⁵.

In addition, a limitation of the present study is that the antifungal activity was evaluated using only a single reference strain, *C. albicans* ATCC 90028. Although this strain is widely used in antifungal research, clinical isolates may exhibit different adhesion and susceptibility profiles. Furthermore, the

present investigation focused on the initial adhesion stage after 4 h of incubation and did not evaluate the effects of the tested solutions on formed and mature biofilms (24 h and 72 h, respectively), which are known to exhibit increased resistance to antimicrobial agents. Moreover, denture stomatitis is a complex polymicrobial condition in which *Candida* species interact with bacterial communities and host factors. Therefore, the present findings should be interpreted as preliminary evidence of anti-adhesion activity against early fungal colonization. Future studies should therefore investigate the effects of the extract on mature mono- and multispecies biofilms using a broader range of clinical isolates, to better reflect clinical conditions.

Conclusion

The herbal extract obtained from *R. nigrum* fruits preserved the mechanical properties of PMMA, including hardness and Young's modulus, unlike the tested commercial denture cleansers (Corega and Protefix). In addition, the extract significantly reduced *C. albicans* adhesion to PMMA surfaces after 4 h of incubation. These findings indicate that *R. nigrum* extract may have potential as a natural agent for denture hygiene. However, the results are based solely on in vitro experiments involving a single reference strain and early adhesion stage. Therefore, further studies are required to evaluate the effects of extract on mature and polymicrobial biofilms, cytotoxicity, long-term material stability and color stability before any clinical application can be considered. **Grant**

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Conflict of interest

The authors declare no conflict of interest.

References

1. Azevedo A, Machado AL, Vergani CE, Giampaolo ET, Pavarina AC, Magnani R. Effect of Disinfectants on the Hardness and Roughness of Reline Acrylic Resins. *J Prosthodont*. 2006;15(4):235-242.
2. Koseki Y, Tanaka R, Murata H. Development of antibacterial denture cleaner for brushing containing tea tree and lemongrass essential oils. *Dent Mater J*. 2018;37(4):659-666.
3. Petrović M, Kitić D, Samardžić N, Kostić M, Stojanović G, Igić M, et al. The effect of herbal extract *Foeniculum vulgare* mill. solution on the mechanical and wetting properties of heat polymerized denture base resin. *Acta Stomatol Naissi*. 2016 Dec; 32(74):1623-34.
4. Paranhos HFO, Silva-Lovato CH, Souza RF, Cruz PC, Freitas KM, Peracini A. Effects of mechanical and chemical methods on denture biofilm accumulation. *J Oral Rehabil*. 2007;34(8):606-612.
5. Lucena-Ferreira SC de, Ricomini-Filho AP, Silva WJ da, Cury JA, Cury AADB. Influence of daily immersion in denture cleanser on multispecies biofilm. *Clin Oral Investig*. 2014;18(9):2179-2185.
6. Neppelenbroek KH, Pavarina AC, Vergani CE, Giampaolo ET. Hardness of heat-polymerized acrylic resins after disinfection and long-term water immersion. *J Prosthet Dent*. 2005;93(2):171-176.
7. Kang YS, Rueggeberg F, Ramos V. Effects of chlorine-based and quaternary ammonium-based disinfectants on the wettability of a polyvinyl siloxane impression material. *J Prosthet Dent*. 2017;117(2):266-270.
8. Petrovic M, Bonvin D, Todoc J, et al. Surface modification of poly(methyl-methacrylate) with farnesol to prevent *Candida* biofilm formation. *Lett Appl Microbiol*. 2022 Oct; 75(4):982-990.
9. Petrović M, Randjelović M, Igić M, et al. Poly(methyl methacrylate) with Oleic Acid as an Efficient *Candida albicans* Biofilm Repellent. *Materials*. 2022;15(11):3750.
10. Petrović M, Bonvin D, Hofmann H, Mionić Ebersold M. Fungicidal PMMA-Undecylenic Acid Composites. *Int J Mol Sci*. 2018;19(1):184.
11. Ozyilmaz OY, Akin C. Effect of cleansers on denture base resins' structural properties. *J Appl Biomater Funct Mater*. 2019;17(1):2280800019827797.
12. Moussa AR, Dehis WM, Elboraey AN, ElGabry HS. A Comparative Clinical Study of the Effect of Denture Cleansing on the Surface Roughness and Hardness of Two Denture Base Materials. *Open Access Maced J Med Sci*. 2016;4(3):476-481.
13. Yuzugullu B, Acar O, Cetinsahin C, Celik C. Effect of different denture cleansers on surface roughness and microhardness of artificial denture teeth. *J Adv Prosthodont*. 2016;8(5):333-338.

14. Kiesow A, Sarembe S, Pizzey RL, Axe AS, Bradshaw DJ. Material compatibility and antimicrobial activity of consumer products commonly used to clean dentures. *J Prosthet Dent.* 2016;115(2):189-198.e8.
15. Macêdo LO, Campos DES, da Nóbrega Alves D, Carreiro A da FP, de Castro RD, Batista AUD. Effects of long-term cinnamaldehyde immersion on the surface roughness and color of heat-polymerized denture base resin. *J Prosthet Dent.* 2022;128(3):521.e1-521.e8.
16. Papadiochou S, Polyzois G. Hygiene practices in removable prosthodontics: A systematic review. *Int J Dent Hyg.* 2018;16(2):179-201.
17. Oliveira J de A, da Silva ICG, Trindade LA, et al. Safety and Tolerability of Essential Oil from *Cinnamomum zeylanicum* Blume Leaves with Action on Oral Candidosis and Its Effect on the Physical Properties of the Acrylic Resin. *Evid Based Complement Alternat Med.* 2014;2014:e325670.
18. Tulbah HI. Anticandidal efficacy on polyimide based denture resin using Photodynamic therapy, chemical and herbal disinfectants and their effect on surface roughness and hardness. *Photodiagnosis Photodyn Ther.* 2022;39:102874.
19. Songsang N, Anunmana C, Pudla M, Eiampongpaiboon T. Effects of *Litsea cubeba* Essential Oil Incorporated into Denture Soft Lining Materials. *Polymers.* 2022;14(16):3261.
20. Martínez A, Catalán A, Rojas N, Torres V, Acuña M. In Vitro Effectiveness of a Terpenic Denture Cleanser on Old Biofilm Surfaces. *J Prosthodont.* 2018;27(1):57-62.
21. Miladinović B, Kostić M, Šavikin K, et al. Chemical profile and antioxidative and antimicrobial activity of juices and extracts of 4 black currants varieties (*Ribes nigrum* L.). *J Food Sci.* 2014;79(3):C301-309.
22. Miladinović B. Potential use of black currants (*Ribes nigrum* L.) juices and extracts as functional food. [PhD Thesis]. Niš: Faculty of Medicine, University of Niš; 2015.
23. Ramage G, Zalewska A, Cameron DA, et al. A Comparative In Vitro Study of Two Denture Cleaning Techniques as an Effective Strategy for Inhibiting *Candida albicans* Biofilms on Denture Surfaces and Reducing Inflammation. *J Prosthodont.* 2012;21(7):516-522.
24. Kováč J, Slobodníková L, Trajčiková E, et al. Therapeutic Potential of Flavonoids and Tannins in Management of Oral Infectious Diseases—A Review. *Molecules.* 2023;28(1):158.
25. Rizwana H, Alwhibi MS, Al-Judaie RA, Aldehaish HA, Alsaggabi NS. Sunlight-Mediated Green Synthesis of Silver Nanoparticles Using the Berries of *Ribes rubrum* (Red Currants): Characterisation and Evaluation of Their Antifungal and Antibacterial Activities. *Molecules.* 2022;27(7):2186.

26. Staszowska-Karkut M, Materska M. Phenolic Composition, Mineral Content, and Beneficial Bioactivities of Leaf Extracts from Black Currant (*Ribes nigrum* L.), Raspberry (*Rubus idaeus*), and Aronia (*Aronia melanocarpa*). *Nutrients*. 2020;12(2):463.
27. Rocha M, Carvalho AM, Coimbra FCT, et al. Complete denture hygiene solutions: antibiofilm activity and effects on physical and mechanical properties of acrylic resin. *J Appl Oral Sci Rev FOB*. Published online 2021.
28. Bensel T, Bock JJ, Kebernik A, Arnold C, Mansour S, Boeckler AF. Effect of Disinfectants on Mechanical Properties of Orthodontic Acrylics. *Int J Biomater*. 2019;2019:e1096208.
29. Gad MM, Abualsaud R, Fouda SM, et al. Effects of Denture Cleansers on the Flexural Strength of PMMA Denture Base Resin Modified with ZrO₂ Nanoparticles. *J Prosthodont*. 2021;30(3):235-244
30. Doğan A, Bek B, Cevik NN, Usanmaz A. The effect of preparation conditions of acrylic denture base materials on the level of residual monomer, mechanical properties and water absorption. *J Dent*. 1995;23(5):313-318.
31. Cucci AL, Vergani CE, Giampaolo ET, Afonso MC. Water sorption, solubility, and bond strength of two autopolymerizing acrylic resins and one heat-polymerizing acrylic resin. *J Prosthet Dent*. 1998;80(4):434-438.
32. Sasaki H, Hamanaka I, Takahashi Y, Kawaguchi T. Effect of long-term water immersion or thermal shock on mechanical properties of high-impact acrylic denture base resins. *Dent Mater J*. 2016;35(2):204-209.
33. Braun KO, Mello J a. N, Rached RN, Del Bel Cury AA. Surface texture and some properties of acrylic resins submitted to chemical polishing. *J Oral Rehabil*. 2003;30(1):91-98.
34. Durkan R, Ayaz EA, Bagis B, Gurbuz A, Ozturk N, Korkmaz FM. Comparative effects of denture cleansers on physical properties of polyamide and polymethyl methacrylate base polymers. *Dent Mater J*. 2013;32(3):367-375.
35. Rocha G dos SR, Duarte TN, Corrêa G de O, Nampo FK, Ramos S de P. Chemical cleaning methods for prostheses colonized by *Candida* spp.: A systematic review. *J Prosthet Dent*. 2020;124(6):653-658.
36. Atalay S, Çakmak G, Fonseca M, Schimmel M, Yilmaz B. Effect of different disinfection protocols on the surface properties of CAD-CAM denture base materials. *J Prosthet Dent*. Published online 8 February 2022:S0022-3913(21)00692-2.

37. Da Silva FC, Kimpara ET, Mancini MNG, Balducci I, Jorge AOC, Koga-Ito CY. Effectiveness of Six Different Disinfectants on Removing Five Microbial Species and Effects on the Topographic Characteristics of Acrylic Resin. *J Prosthodont*. 2008;17(8):627-633.
38. Pogorzelski SJ, Berezowski Z, Rochowski P, Szurkowski J. A novel methodology based on contact angle hysteresis approach for surface changes monitoring in model PMMA-Corega Tabs system. *Appl Surf Sci*. 2012;258(8):3652-3658.
39. Nowak J, Steinberg K, Sokołowski J, Bociog K. Influence of various class cleaning agents for prosthesis on Co–Cr alloy surface. *Open Chem*. 2022;20(1):958-969.
40. de Andrade IM, Cruz PC, da Silva CHL, et al. Effervescent tablets and ultrasonic devices against *Candida* and mutans streptococci in denture biofilm. *Gerodontology*. 2011;28(4):264-270.
41. Shetty PJ, Hegde V, Gomes L. Anticandidal efficacy of denture cleansing tablet, Triphala, Aloe vera, and Cashew leaf on complete dentures of institutionalized elderly. *J Ayurveda Integr Med*. 2014;5(1):11-14.
42. Hayran Y, Sarikaya I, Aydin A, Tekin YH. Determination of the effective anticandidal concentration of denture cleanser tablets on some denture base resins. *J Appl Oral Sci Rev FOB*. 2018;26:e20170077.
43. Song YG, Lee SH. Efficacy of newly developed denture cleaning device on physical properties of denture material and *Candida* biofilm. *J Dent Sci*. 2019;14(3):248-254.
44. Raszewski Z, Nowakowska D, Więckiewicz W, Nowakowska-Toporowska A. The Effect of Chlorhexidine Disinfectant Gels with Anti-Discoloration Systems on Color and Mechanical Properties of PMMA Resin for Dental Applications. *Polymers*. 2021;13(11):1800.