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Dr. Ali Hafez Quran
Department of prosthodontics, Faculty of dentistry, Tabriz University of medical sciences, Tabriz, Iran

Dr. Roodabah Koodaryan
Department of prosthodontics, Faculty of dentistry, Tabriz University of medical sciences, Tabriz, Iran

Ali Saadoon Khudhair
Department of prosthodontics, Faculty of dentistry, Tabriz University of medical sciences, Tabriz, Iran

Corresponding Author:
Dr. Ali Hafez Quran
Department of prosthodontics, Faculty of dentistry, Tabriz University of medical sciences, Tabriz, Iran

The effect of propolis disinfectant solution on mechanical and physical properties of polycarbonate denture base

Dr. Ali Hafez Quran, Dr. Roodabah Koodaryan and Ali Saadoon Khudhair

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Abstract

Introduction: The prosthesis base materials should have the necessary and sufficient quality to resist the various chemical compounds in the mouth and various pressures. This study investigates the effect of propolis disinfectant solutions on the mechanical and physical properties of polycarbonate prosthesis base materials.

Materials and Methods: In this study, 120 polycarbonate samples were prepared and analyzed in 4 main groups (to test impact strength, hardness, surface roughness, and color stability) and 3 subgroups (control, 5% propolis, and 10% propolis). Rod samples with a length of 80 mm, a width of 10 mm, and a thickness of 4 mm were used for the impact strength test, Rod samples with a length of 65 mm, a width of 10 mm, and a thickness of 2.5 mm were used for surface roughness test and hardness test, and rectangular sample with a length of 20 mm, a width of 10 mm, and a thickness of 0.8 mm were used for color stability. After flasking, polycarbonate injection was done to prepare 30 samples of each. All the samples were finished and polished, except for the surface roughness test samples, which were only finished. Ten samples from each group were immersed in distilled water, 10 samples in 5% propolis solution, and 10 samples in 10% propolis solution for 10 minutes at room temperature. This process was repeated 180 times. Then, impact strength, hardness, surface roughness, and color stability tests were performed. Data were analyzed in SPSS 22 software using One-way ANOVA, Kruskai Wallis, and Mann-Whitney tests.

Results: Disinfection solutions of 5 and 10% propolis did not cause significant changes in the hardness and impact resistance of the polycarbonate denture base compared to the control group (distilled water). Significant reduction of the surface roughness of the polycarbonate denture base by immersion in 5 and 10% solutions Propolis was observed compared to the control group (distilled water) (P value=0.003), but there was no significant difference between the two concentrations of 5% and 10% of propolis. Also, immersion in 5% and 10% propolis solutions caused a significant change in the color of the polycarbonate denture base compared to the control group distilled water (P value=0.003), but there was no significant difference between the two concentrations of 5% and 10% propolis. Of course, this color change was not clinically detectable ($\Delta E < 1$).

Conclusion: Concentrations of 5 and 10% of Propolis solution did not cause an unfavorable impact on the hardness, impact strength, and surface roughness of the polycarbonate denture base. Thus, it can be used as a disinfection solution for polycarbonate denture bases.

Keywords: Polycarbonate denture base, Propolis, hardness, impact strength, surface roughness, color stability

Introduction

The prosthesis should be aesthetically attractive, perform well, and be biocompatible with the surrounding oral tissues supporting it. A successful prosthesis should be dimensionally compatible to improve chewing performance, be comfortable for patients, and prevent inflammation of oral tissues [1]. Polycarbonate or PC (bisphenol (A) is an amorphous polymer with crystalline regions in certain parts [2]. PC has exceptional mechanical properties such as structural stability, excellent impact strength [3], high plastic deformation without breaking or cracking [4], low water absorption, no tissue irritation due to the absence of monomers [3, 5, 6], and high thermal resistance. It maintains its properties in a wide range of temperatures (140 °C to -20 °C) [5].

Regarding these properties, it has shortcomings such as low chemical tolerance, limited scratch resistance, and sensitivity to UV rays, causing discoloration. PC may be improved by adding appropriate additives or mixing it with other polymers [3].

Propolis is a resinous and waxy substance made by bees from the buds of spruce and coniferous trees. Propolis seems to help fight bacteria and fungi, may also have anti-inflammatory effects, and may help heal minor skin wounds, promote oral hygiene, and treat herpes. Propolis antibacterial, antifungal, antiviral, anti-inflammatory, and anti-cancer properties have been proven. Also, propolis prevents the formation of calcium phosphate, which is the primary component of dental plaque [7]. The antibacterial activity of propolis should be considered on two levels. First, it is related to the direct impact on the microorganism, and the other is related to the stimulation of the immune system and the activation of the natural defense of the organism [8]. The mechanisms of propolis are related to the permeability of the microorganism's cell membrane, disturbance in the membrane potential and the production of adenosine triphosphate (ATP), and the reduction of bacterial motility [9, 10].

Sadrabad *et al*. showed that propolis can improve denture stomatitis in patients using removable dentures [11]. Da Silva *et al*. examined the impacts of nystatin, fluconazole, and propolis on the surface of poly (methyl methacrylate) resin. They observed that propolis can induce changes in (1PMMA) surface properties, such as roughness, which can be related to microbial adhesion [12]. Firouz *et al*. showed that the surface roughness of heat-cured denture base resin exposed to 5.25% sodium hypochlorite increases dramatically [13]. In the study conducted by Mr. Hatem *et al*. regarding the use of chlorhexidine and sodium hypochlorite disinfectants on polycarbonate, the impact strength of polycarbonate decreased significantly after immersion. Additionally, the surface hardness increased by 2% after immersion in chlorhexidine and showed a significant reduction after immersion in sodium hypochlorite by 25%. Surface roughness increased slightly after immersion in each solution [14].

Given the many benefits of propolis, the present study investigates the effect of propolis disinfectant solutions on the mechanical and physical properties of polycarbonate prosthesis base materials to investigate the possibility of using it to disinfect dentures.

Materials and Methods

In this experimental study, 120 polycarbonate samples were prepared and analyzed in 4 main groups (to test impact strength, hardness, surface roughness, and color stability) and 3 subgroups (control, 5% propolis, and 10% propolis). The sample size was calculated using power & sample size software and Considering α=0.05, 80% power and 10% error, [15].

1. **Investigating impact strength:** Control group (n=10), 5% propolis solution (n=10), and 10% propolis solution (n=10).
2. **Hardness test:** Control group (n=10), propolis solution 5% (n=10), and 10% (n=10).
3. **Investigating surface roughness:** Control group (n=10), propolis solution 5% (n=10), and 10% (n=10).
4. **Investigating color stability:** Control group (n=10), propolis solution 5% (n=10), and 10% (n=10).

Table 1: Materials used in the study

No.	Material	Manufacturer	Source	Expire Date
1.	Base plate wax	Shanghai New Century Dental Materials Co.	China	12\2025
2.	Polycarbonate	Extra rigid polymer M10 XR, Deflex	Argentina	8\2025
3.	Dental stone	Kimberlit extra hard high density die stone	Spain	8\2026
4.	Distilled water	Iraq	Iraq	8\2026
5.	Performed wax tubes	Deflex	Argentina	8\2025
6.	Isodent separating solution	Spofa Dental	Czechoslovakia Europe	11\2024
7.	Propolis	Rayehe	Iran	10/2026

Incubation of the specimens

Each test specimens' group was gathered and placed in plastic containers and filled with distilled water and were placed in incubator for 48 hours at 37 °C according to ADA 1999 Specification No. 12 in 1999 to remove any residual by products.

According to the existing standards, four plastic models were prepared for testing impact strength, hardness, surface roughness, and color stability with a CNC (Computer Numerical Control) machine. A laser cutting machine was used to prepare the acrylic pattern after designing by computer software (Auto CAD 2015).

After flasking, polycarbonate injection was performed to prepare 30 samples of each (120 samples in total). All the samples were finished and polished, except for the surface roughness test samples, which were only finished, and no polishing was done. Polycarbonate samples were removed using a metal disc for cutting. Then, each sample was finished using special plastic burs and sandpaper. The samples were polished in a polishing machine using a soft brush with pumice and rouge. Ten samples from each group are immersed in distilled water, 10 samples in 5% propolis solution, and 10 samples in 10% propolis solution (16) for 10 minutes at room temperature. This process was repeated 180 times [17].

Testing mechanical and physical properties

1. Impact strength test: Bar shaped specimens with length, width, and thickness of (80 mm × 10 mm ×4 mm) (ISO. 179-1, 2000 for unnotched specimens) were constructed. According to ISO (International Organization of Standardization), it will be tested by a Charpy impact strength testing machine. The sample is placed horizontally, held at its end, and is struck by a freely rotating pendulum. The impact strength is expressed in joules with a reading scale next to the Charpy- type impact testing device. The Charpy impact strength of the uncut sample was calculated in KJ/m2 with the following equation: Impact strength = E/B. D × 103 (KJ/m2)

E: The absorbed energy of the impact is in Joules.

B: The width of the samples is in millimeters.

D: The thickness of the test samples [18].

2. Hardiness: Bar shaped specimens with dimensions of (65 mm×10 mm × 2.5±0.1 mm) length, width and thickness

respectively were prepared.
A Shore D length gauge (according to ASTM D2240-03 standard) was used, which is suitable for all test materials. The test instrument consists of a 1.40 mm diameter slow indenter with a 30-degree taper, a gauge graduated from 0 to 100, and a fixed base on which the specimen is placed to perform the hardness test.

3. Surface roughness: The samples of surface roughness were similarity of the samples of hardness. A portable digital roughness meter (Profilometer) with an accuracy of 0.001 micrometers was used to measure surface roughness following Profilometer guidelines. This tester includes a sensitive diamond needle which is used to detect irregularities on the surface.

4. Color stability: Rectangular-shaped samples with diameter of 20 mm length, 10 mm width and thickness of 0.8 mm were fabricated for color stability test.

The rate of light transmission of the sample was measured using a spectrophotometer as a function of wavelength. The sample was placed on the optical opening of the device and then exposed to light. Then, the percentage and reading of the transmitted light were obtained from the computer screen connected to the device.
The collected data were analyzed using SPSS 22 softwareat statistics. To compare the investigated variables (impact strength, surface roughness, and hardness) in the studied groups, due to the normal distribution, One-way ANOVA (analysis of variance) be used. If it is significant, Tukey's post hoc test be used. Due to the non-normal distribution of the data, Kruskai Wallis and Mann Whitney tests be used for comparing the color stability. The confidence level of the tests was considered to be 95% ($\alpha<0.05$).

Results

Results above shows that all studied variables except the color stability variable, among groups are normally distributed variables using Shapiro Wilk test at p greater than 0.05. The color stability variable does not have a normal distribution (Table 1).

Impact Strength Test: Results show that the average in the control group is 211.28 ± 23.15 KJ/m^2 in the 5% Propolis group is 221.36±222.23 KJ/m^2 and in the 10% Propolis group it is 209.25±22.56 KJ/m^2. One-way ANOVA table for impact resistance test results did not show any significant difference between all test groups (Table 2).

Shore D hardness tests: Results show that the average in the control group is 81.12±1.06 in the 5% Propolis group is 82.18±1.24 and in the 10% Propolis group it is 81.48±1.08. One-way ANOVA table for hardness test results did not show any significant difference between all test groups (table 2).

Surface Roughness Test: Results show that the average in the control group is 211.28 ± 23.15 Mm in the 5% Propolis group is 221.36±222.23 Mm and in the 10% Propolis group it is 209.25 ± 22.56 Mm. One-way ANOVA table for surface roughness test results showed a significant difference between all test groups (table 2).

Tukey HSD test was performed to compare two groups. The surface roughness in the control group was significantly higher than the 5 and 10% Propolis groups. The two groups of Propolis had no significant differences in terms of surface roughness (Table 3).

Color Stability Tests
Table 2 shows the values of UV absorption to check the amount of color change in each group. The average UV absorption in the control group was 3.19±1.21, 3.95±0.006 in the 5% propolis group, and 3.82±0.17 in the 10% propolis group. Kruskal-Wallis table for color fastness results showed a significant difference between all test groups (Table 2).
Mann-Whitney test was used to compare two groups. The average UV absorption in the control group was significantly lower than the 5% and 10% propolis groups. There was no significant difference between the two groups of Propolis in terms of UV absorption mean (Table 3).

Table 1: Tests of Normality of studied variables by groups using Shapiro Wilk test

Variables	Groups	Shapiro wilk P value ^
Impact strength (Kj/m^2)	Control group	0.053
	5% Propolis	0.178
	10% Propolis	0.624
Hardness (Shore D)	Control group	0.251
	5% Propolis	0.954
	10% Propolis	0.177
Surface roughness (µm)	Control group	0.351
	5% Propolis	0.05
	10% Propolis	0.726
Color stability	Control group	0.001
	5% Propolis	0.031
	10% Propolis	0.257

Table 2: Below shows the mean values, standard deviation, strength test, hardness, Surface Roughness and Color Stability findings

Group	N	Impact Strength		Shore D hardness		Surface Roughness		Color Stability	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Control	10	211.28	23.15	81.12	1.06	1.94	0.34	3.19	1.21
5% Propolis	10	221.36	22.23	82.18	1.24	1.34	0.42	3.95	0.06
10% Propolis	10	209.25	22.56	81.48	1.08	1.49	0.36	3.82	0.17
P-value		.489*		.122*		.003*		.023**	

Not significant at p>0.05, significant at p<0.05.
*: One-way ANOVA, **: Kruskal-Wallis

Table 3: Tukey HSD test between all studies groups for surface roughness test

(I) group	(J) group	Surface roughness test		UV absorption	
		Mean Difference (I-J)	P-value*	Mean Difference (I-J)	P-value**
Control	5% Propolis	0.606	0.003	-0.7584	0.014
Control	10% Propolis	0.453	0.030	-0.6289	0.034
5% Propolis	10% Propolis	-0.153	0.636	0.1295	0.824

P-value*: Tukey HSD test
P-value**: Mann-Whitney test

Discussion

The present study examined the effect of propolis disinfectant solutions on the mechanical and physical properties of polycarbonate prosthesis base materials. The chemical immersion technique is the selected method for cleaning dentures. Propolis is a natural and biocompatible substance that has antioxidant, antibacterial, antifungal, antiviral, and anti-inflammatory properties [7, 9, 10]. The chemical composition of propolis indicates that it is a potential source of natural compounds with many medicinal effects and therapeutic applications. The antimicrobial effects of propolis are directly associated with its concentration since the concentration causes a change in the amount of flavonoid compounds. Based on most of the studies conducted on propolis, concentrations of 5% and 10% of propolis were used in this study.

Effect of disinfection on Surface roughness of polycarbonate: With increasing the roughness of the denture base surface, C. albicans colonization and adhesion will more occur [19]. Microbial adhesion and plaque accumulation are affected by the surface roughness of the prosthesis base material [20, 21]. Rough denture base surfaces provide more surface area for microbes to adhere to. Rough surfaces help trap microorganisms. The roughnes of the prosthesis is affected by the material properties, polishing techniques, and operator skills [22]. Denture base surfaces should have a smooth and scratch- free surface since increasing the surface roughness can also reduce the beauty of the denture, while reducing the surface roughness improves the beauty of the prosthesis, and reduces the accumulation of bacteria and plaque formation [23].

In the present study, disinfectant solutions containing propolis caused a significant reduction in the surface roughness of polycarbonate compared to the control group (distilled water). The results of the present study indicate the positive effect of propolis in reducing surface roughness and thus reducing microbial adhesion and plaque accumulation in the denture base. However, increasing the propolis concentration did not significantly affect the surface roughness. The reduction in the roughness can be due to the gummy and resinous state of propolis, and the increase in the concentration of propolis has no role in this resinous state. Propolis is primarily composed of plant resins (60%), pollen, and wax (up to 30%).

Propolis may be responsible for reducing the hydrophilicity of the polycarbonate surface. As hydrophilicity decreases, fewer ester bonds are attacked by water. Reducing the number of molecular chains per cross-sectional area unit and reducing the number of connections reduces the surface roughness [24, 25]. However, unlike the results of the present study, the results of a study by Al-Khalifa *et al*. (2022) revealed an increase in surface roughness due to the addition of 2.5% of propolis extract (CAPE) in auto-polymerized acrylic resin [26]. The reason for this difference can be related to the type of substance under investigation and the type of extract in this study.

Effect of disinfection on hardness of polycarbonate

In the present study, disinfectant solutions containing propolis did not cause significant changes in the hardness of polycarbonate compared to the control group (distilled water). In this test, a shore durometer hardness tester, which is suitable for determining the hardness of denture bases, was used. The shore durometer hardness tester overcomes the problem of elastic recovery due to its design. This method directly measures the depth of loaded indentations by a screen that displays their number [27].

Consistent with the present study, in the study by Miranda *et al*. (2019), the values of Shore A hardness of two jaw and face elastomers at the beginning and after 60 days of immersion in Brazilian green propolis solution did not show statistically a significant difference [28]. Based on the study by Cardoso *et al*. (2016), Brazilian wild green propolis did not affect the reduction of enamel minerals [29]. However, some studies presented conflicting results. In this regard, the study by Naeem *et al*. (2023) revealed that the use of propolis as an intracanal drug significantly increases the micro-hardness of root dentin. However, chlorhexidine solution reduces the micro-hardness of root dentin [30].

The study by Al-Khalifa *et al*. (2022) also showed a reduction in the hardness of acrylic resin with the addition of propolis extract (CAPE) [26]. Hardness is defined as a material's resistance to wear opposing tooth structures. Hardness is a common approach to exploring the factors that affect resin conversion rates since the mechanical properties of a polymer can be determined due to the simplicity of the process. Giamalia *et al*. (1999) examined the impact of exposure to propolis on the micro-hardness of human tooth enamel in laboratory conditions. The dissolved calcium concentration was 7.8 ppm and the pH values varied between 5 and 6. The fluoride concentration was negligible. With increasing the percentage of propolis in the solution, the Vickers hardness number of the exposed enamel showed a constant increase. The increase in micro-hardness can be attributed to certain components of mineralization activity in propolis [31].

Effect of disinfection on impact strength of polycarbonate

In the present study, disinfectant solutions containing propolis did not cause significant changes in the impact strength of polycarbonate compared to the control group (distilled water). One of the most significant properties of polycarbonate is scratch and impact strength. Hajinezhad *et al*. (2020) observed that the tensile strength of low-density polyethylene (LDPE) films decreased with the addition of propolis. However, they showed that the addition of propolis (5 to 20% by weight) to the LDPE polymer matrix does not cause significant changes in the chemical structure and mechanical properties. In other words, it revealed a lack of a strong interaction between LDPE and propolis [32].

One of the factors affecting the properties of propolis and the results of studies is the use of different types of propolis. The study by Gonçalves *et al*. (2021) revealed that the use of 0.5% brown propolis did not affect the bond strength of fiberglass posts to root canal dentin, while the use of 0.25% green propolis negatively affected it [33].

Effect of disinfection on Color Stability of polycarbonate

In the present study, disinfectant solutions containing propolis caused a significant color change (increased UV absorption) in polycarbonate compared to the control group (distilled water). But concentrations of 5 and 10% propolis did not have a significant difference in the roughness of the polycarbonate surface. In the present study, a spectrophotometer was used to measure the color changes. In light of this method, it is possible to change small color changes that cannot be detected by the eye. The color difference between the samples containing propolis and the control group was clinically insignificant. Based on the studies, when the mean color difference was less than (one), the color difference was clinically insignificant.

Based on the results of Miranda *et al*., an 11% alcoholic propolis extract solution causes changes in the optical parameters of jaw and face elastomers. This change in color and transparency was clinically unacceptable. Çelik *et al*. (2023) reported that microfilament and microhybrid composite discs had clinically unacceptable color changes at 12 and 24-hour periods in propolis extract solution. Based on the results of these researchers, the ratio of phenolic and flavonoid compounds in each herbal formula plays a more significant role in the color change potential [34].

According to the results of the present study, it is suggested that studies with the aim of investigating other concentrations of propolis, investigating the microscopic changes of the polycarbonate surface under the influence of propolis, and investigating the use of standard solutions of gold and chlorhexidine as a control group are also conducted.

Conclusions

- Disinfection solutions of 5 and 10% propolis did not cause significant changes in the hardness of the polycarbonate denture base compared to the control group (distilled water).
- A significant reduction in the surface roughness of the polycarbonate denture base was observed by immersion in 5 and 10% propolis solutions compared to the control group (distilled water). But the two concentrations of propolis did not have a significant difference in the surface roughness.
- Disinfection solutions of 5 and 10% propolis did not cause significant changes in the impact strength of the polycarbonate denture base compared to the control group (distilled water).
- Significant color change of polycarbonate denture base was observed by immersion in 5% and 10% propolis solutions compared to the control group (distilled water). But concentrations of 5 and 10% propolis had no significant difference in the color stability of the polycarbonate surface.

Conflict of Interest

Not available

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Not available

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