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RESEARCH ARTICLE - MEDICAL TECHNIQUES

Evaluate the Influence of Various Drinking Solutions on the Hardness of Thermoplastic Nylon Materials

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Abstract

Background: Flexible resins were first developed for the manufacture of RPD prostheses. They are recommended for the fabrication of RPDs, primarily for anterior teeth, when aesthetics are important. This is due to its opacity and natural look. Furthermore, the flexibility of these materials reduces fractures in prostheses. Its modest weight also contributes to patient comfort. Aim: This research aimed to determine the influence of drinks on the hardness of acrylic flexible dentures. Material and methods: A total of 28 flexible acrylic resin specimens with dimensions of 2.5×10×65mm in depth, width, and length were divided into four groups based on the solution that would immerse the specimens inside; each group had seven specimens: (A) the control group immersed in distal water; (B) the group immersed inside the soft drink (Pepsi); (C) the group specimens immersed inside the coffee; and (D) the group specimens immersed inside the tea for 30 days. The degree of hardness of each specimen was then determined. SPSS version 23 was used to statistically analyze the obtained data. Results: The findings of this study demonstrate that group A had the highest mean value for micro-hardness testing and group D had the lowest mean value. Conclusions: A significant difference was observed in groups B (Pepsi) and D (tea) as compared to groups A (distilled water) and C (coffee).

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Keywords: Flexible Denture Base Material; Surface Hardness; Pepsi; Coffee; Tea.

1. Introduction

A flexible denture is a type of partial denture made of elastic nylon resin that is more flexible than plastic. Patients can wear flexible, complete and partial dentures with greater comfort because there is no clasp needed because they are anchored to the gum. For many years, soft temporary crowns and thermally polymerized crowns made of polymethyl methacrylate have been used in dentistry [1]. The first thermo-polymerizable acrylic resins were developed in 1936, representing a significant advancement in dental technology. Poly (methyl methacrylate), or PMMA, is another name for acrylic resins. They are synthetic materials that may be sculpted, packed, or injected into molds during an early plastic phase before solidifying via a chemical reaction called polymerization [2]. In the 1950s, two flexible denture base materials, Valplast and Flexiplast, were first introduced to dentistry. These materials and fluid resins are utilized in the process of injection molding to create a variety of prostheses [3]. Traditional dentures can be replaced with flexible ones because they provide partially edentulous people with good look, security, and responsiveness to their ongoing mobility and flexibility [4]. Biocompatibility, strength, durability, adequate thermal characteristics, chemical stability, and color stability are some of the parameters for a clinically appropriate denture base material [5]. The main disadvantage of this material is polymerization shrinkage, which is an important factor for the retention and durability of prostheses. Water sorption by the acrylic resin, gingival mucosa resilience, and salivary activity may compensate for this impact. The discharge of methylmethacrylate might induce hypersensitivity and mucosal irritation. Another issue that arises while supplying acrylic prostheses is a lack of strength and design in satisfying the functional demands of the oral cavity [6]. These disadvantages are related to the water sorption and solubility characteristics of acrylic resin polymers. Water absorption is affected by the material's hydrophobicity and porosity [7]. Absorbed water reduces the strength of the resin denture base as well as the material's physical and mechanical characteristics [8]. Although the characteristics of acrylic resin materials have grown, there are still problems with their physical qualities, chemical compositions, and polymerization techniques. Problems such as brittleness, color changes, and porosity [9]. The goal of this research is to evaluate the influence of various drinking solutions on the hardness of thermoplastic nylon denture base material.

2. Materials and Methods

2.1. Mould preparation

Base and catalyst silicone materials were mixed to make the silicone molds for the test specimens. As indicated in Fig. 1, the study sample was created by pouring silicone over wax specimens by ADA Standard Number 12 [10].

Nomenclature & Symbols			
PMMA	Poly Methylmethacrylate	˚C	Degree Centigrade
ml	Milliliter	mm	Millimeter
min	Minutes	ANOVA	Analysis of Variance
gm.	Gram	LSD	Least Significant Differences
rpm	Revolution per Minute	ADA	American Dental Association
hrs.	Hours		

Fig. 1. Silicone mold for wax pattern fabrication

2.2. Wax pattern fabrication

A wax pattern with dimensions of 2.5×10×65mm in depth, width, and length, respectively, was created utilizing a silicon mold and base plate wax material. With the help of the Lacron carving tool and the drop technique, the base plat wax was melted and then gradually added to the mold. Waxing continued until the mold was filled with molten wax that measured 2.5 x 10 ×65 mm in depth, width, and length, and then it was allowed to set. The wax pattern was carefully removed from the silicon mold once it had completely hardened, as shown in Fig. 2 (A&B) [5].

A

B

Fig. 2. Wax specimen fabrication

2.3. Investing and spruing

Using dental stone type 3 (Zhermack, Italy), rectangular wax patterns were put into an injection molding flask. A stone slurry was made (33 ml water/100 g powder) and placed in the bottom of the flask, then it was covered with modeling wax to facilitate the flow of polyamide denture base material into each mold space. Following the initial setting of the stone, the separating media (cold mold seal) was used. A second mixture of dental stones was then poured to the flask's lower half, which was then positioned on top of the upper half. After that, the hydraulic press was used to hold the flask [11]. The wax was removed once the stone had been set by putting the flask in boiling water for five minutes. The flask was then opened and thoroughly washed with boiling water to remove any remaining wax. Then, as shown in Fig. 3 [12], the separating media was applied to the mold's surface [12]. After which, it was allowed to cool.

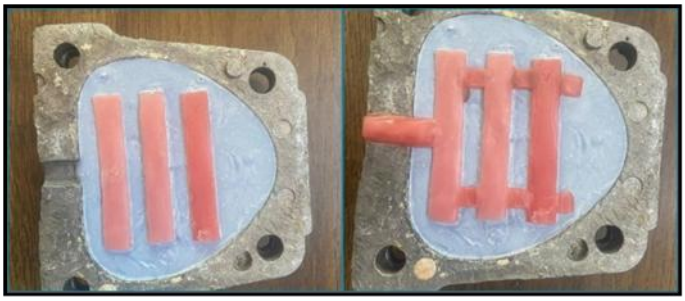

Fig. 3. Spruing & investing

2.4. Injection flexible resin materials

The flexible denture base resin (Valplast International Corp., New York) cartridge was heated using the heating unit by the manufacturer's instructions, as illustrated in Fig. 4. for 20 minutes at 300°C before it was placed on the flask. The bench press pressure was applied to the cartridge, forcing the material via sprues and into the mold cavity. The flask was processed and bench-cooled for two hours.

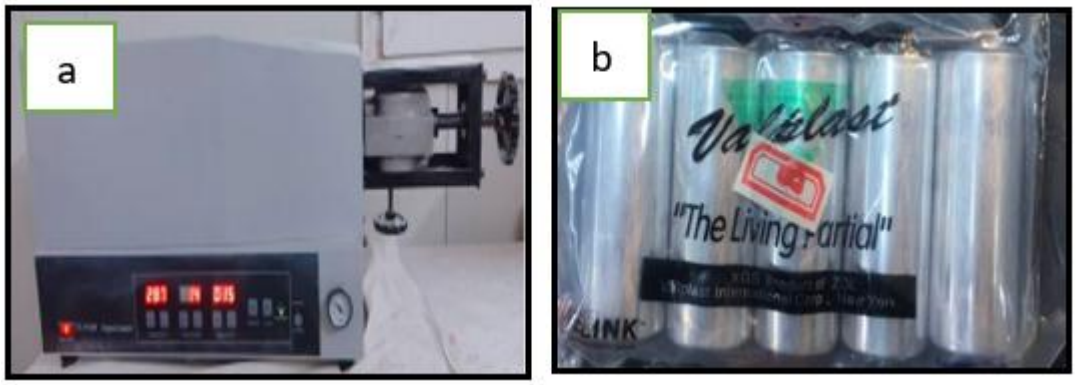

Fig. 4. a) A heating unit device, b) Valplast flexible resin cartridge materials

2.5. Finishing and polishing

To avoid burning the resin material, the sample's sprue was chopped off using a cutting-off disc at low pressure. Each of the 28 examples was hand-finished using a fine grade of silicon carbide paper (grades 120 to 500), stone burs, and sand paper sheets. Water cooling was used throughout the process. Overheating of the sample must be avoided through the finishing processes. The specimen polishing was accomplished by using a bristle brush and pumice with a dental lathe polishing machine using low speed (1500 rpm) with light pressure in only one direction. The sample was moved against the rag wheel. Using a wool brush and polishing soap on the dental lathe, the final shiny finish was created. [13].

2.6. Specimens grouping

Four groups, each including seven specimens, were formed using Valplast flexible acrylic materials to create a total of 28 rectangular-shaped specimens. These specimens were submerged in the various beverage solutions as follows:

- Group A: 7 specimens, which were used as the control group, were submerged in the distal water.
- Group B: 7 specimens were dipped in the soft drink (Pepsi).
- Group C: 7 specimens were dipped in the coffee.
- Group D: 7 specimens were dipped in the tea.

2.7. Prepared beverage solution

A soft drink called Pepsi is produced in Baghdad, Iraq. When they were manufactured, tea and coffee were used as solutions. 30 g of coffee (AlAmeed coffee, France) and 30 g of tea powder (Mahmood tea,Sri Lanka) were used to create the coffee and tea solutions. After adding 1 litter of boiling distilled water, simmering for 5 minutes, and filtering through filter paper, 40 grams of white sugar were added to the tea and coffee solutions and mixed for 5 minutes. [14].

2.8. Immersion procedure

2.8.1. Immersion specimens in the distal water

7 rectangular-shaped flexible acrylic specimens from group A were immersed in the distal water at 37°C (control) for 30 days. Fig. 5a.

2.8.2. Immersion specimens in the soft drink (Pepsi)

Fig. 5b shows the Pepsi solution immersion time for group (B) rectangular-shaped flexible acrylic specimens, which was 10 minutes at 20 ± 1°C. They were then submerged in distilled water for 5 hours and 10 minutes at 37°C. Three times every day, this cycle was repeated, after which the specimens were submerged in distilled water for eight hours per day at a temperature of 22 ± 1°C. The specimens were maintained in distilled water at 37°C until the following immersion cycle, after which they were gently dried with gauze and rinsed with distilled water. This cycle repeated for thirty days [14].

2.8.3. Immersion specimens in the coffee &tea solution

Group C was submerged in a coffee solution, whereas Group D was submerged in a tea solution. Fig. (5c&d) shows samples that were submerged in beverage solutions for 10 minutes at 50 ± 1°C and submerged in distilled water at 37°C for 5 hours, 10 minutes. This cycle was repeated three times each day before being submerged in distilled water for eight hours each day at a temperature of 22± 1°C. The specimens were maintained in distilled water at 37°C until the following immersion cycle, after which they were gently dried with gauze and cleaned with distilled water. For 30 days, this cycle was repeated.[14].

2.9. Surface hardness test

Each sample from the four groups (control, soft drink, coffee, and tea) was tested using a Durometer hardness device type (shore D) to determine the hardness of thermoplastic nylon material. The testing value was determined by averaging six readings made for each sample that were collected directly from the durometer's scale reading using a pointed dibbing instrument [15]. The specimen was placed beneath the indenter region with testing weights applied evenly at 50 N and a measuring depressing time of 10 sec. The digital Shore D tools have an indenter with a diameter of 0.8 mm and a 1.6 mm cylinder. A reading was taken from the digital scale after the indenter had been firmly depressed [16].

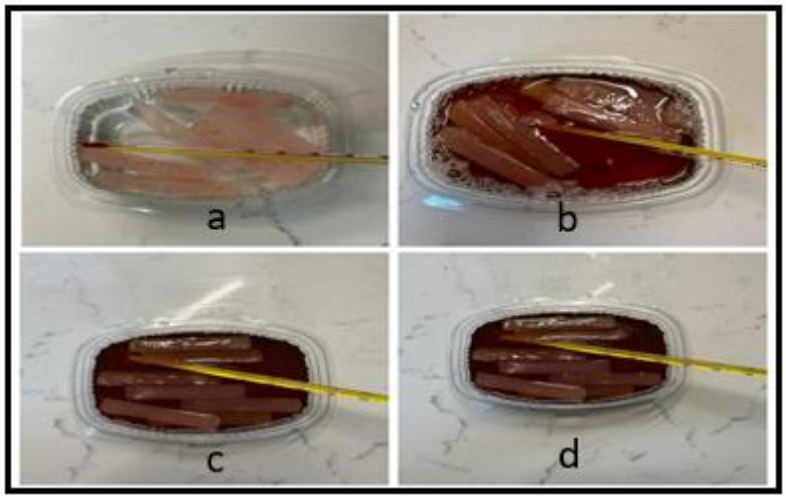

Fig. 5. Samples submerged in drink solutions; (a) Distilled water, (b) Pepsi, (c) tea, and (d) coffee

3. Results

3.1. Surface hardness test

Table 1 shows the descriptive statistics of surface hardness (mean values, standard deviation, and maximum and minimum values). The results showed that (Group A) specimens immersed in distal water had the highest mean value for the hardness test (64.4000), followed by (Group C) specimens immersed in coffee (63.2000), and the lowest mean value was related to both (Group B) specimens immersed in Pepsi and (Group D) specimens immersed in tea (56.8000).

Table 1. Descriptive Statistics for the Groups of Surface Hardness

Groups	N	Mean	Std. Deviation	Maximum values	Minimum values
Distill Water (Control)	7	64.4000	.89443	60.339	68.461
Pepsi	7	56.8000	6.57267	52.739	60.861
Coffee	7	63.2000	3.03315	59.139	67.261
Tea	7	56.8000	4.49444	52.739	60.861
Total	28				

Based on the ANOVA results in Table 2, with an F-value of 4.516 and a significance value of 0.018 (which is less than 0.05), we can conclude that there are statistically significant differences between the groups being studied.

The least significant difference (LSD) test was applied with a level of significance of 0.05 to compare the means of the two groups. According to the results of the test, group A (the control group) specimen immersion in water, group B specimen immersion in Pepsi, and group D specimen immersion in tea were all significantly different from one another ($p< 0.05$), whereas group A (the control group) and group C specimen immersion in coffee were not significantly different ($p > 0.05$), as shown in Table 3.

Table 2. ANOVA- test showing the surface hardness of the testing group specimens

ANOVA	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	248.600	3	82.867	4.516	.018 (HS)
Within Groups	293.600	16	18.350		
Total	542.200	19			

Table 3. LSD test for multiple comparisons of the surface hardness among the different study groups

(I) Groups	(J) Groups	Mean Difference (I-J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Distill Water (Control)	Pepsi	7.6000*	.013	1.8567	13.3433
	Coffee	1.2000	.664	-4.5433	6.9433
	Tea	7.6000*	.013	1.8567	13.3433
Pepsi	Coffee	-6.4000*	.031	-12.1433	-.6567
	Tea	.0000	1.000	-5.7433	5.7433
Coffee	Tea	6.4000*	.031	.6567	12.1433

4. Discussion

After properly finishing and polishing the specimens, surface hardness was assessed using a Digital Shore D durometer by the ASTMD hardness tester. This was done to create a mirror-like surface that was flat and smooth, distributing loads evenly without leaving any scratches behind to ensure precise measurements. The surface hardness test number is very important since it determines how resistant a material is to scratches [17]. PMMA resin is a substance that is frequently used to make denture bases [18]. Due to its inadequate mechanical qualities, the acrylic denture base may fracture while being used. To allow the prosthesis to bear functional forces, the denture base needs to be strong enough. To overcome the shortcomings of PMMA denture base materials, like nylon denture base materials, they have evolved. Nylon is a general term for a subclass of thermoplastic polymers known as polyamides that are largely composed of aliphatic chains [19]. Numerous researchers evaluated and compared the flexural strength of flexible dentures with heat-cure denture base resin materials [19]. However, the research was not focused much on the surface hardness of the flexible materials in the denture base. Surface hardness is also an essential property, along with strength. The base materials for acrylic dentures are poorly resistant to wear and are abraded when the dentures are cleaned regularly. This abrasion causes the surface to become rough, which leads to plaque buildup and makes the denture unhygienic [20]. When compared to flexible denture base materials, heat-cure acrylic resin materials showed greater surface hardness [10]. The lower surface hardness of flexible dentures can be attributed to their greater ductility compared to conventional heat-cured acrylic resins. Therefore, the polymer chains in the flexible denture base materials deform easily under indentation [21]. Consequently, this study was created to assess the surface hardness of flexible denture base materials after being immersed in different beavering solutions. When compared to the mean value of the other groups in the current study, the surface hardness results for the control group (group A) submerged in distilled water indicated a higher mean value, which was (64.4000 ±.89443). Between groups A and groups B and C, a one-way ANOVA revealed a highly significant difference with a P value < 0.05. This outcome may be explained by the specimens' immersion for 30 days at 37°C in just distilled water. The surface hardness of the flexible denture base materials was not affected by the water, which is consistent with Alla et al. [18]. They stated that the crosslinking of the polymer chains could not be affected by water. Table 1 and Fig. 6 showed that Pepsi (group B) and tea (group D) were the most effective beverage solutions for reducing the hardness of flexible materials. The acidic and basic nature of Pepsi and tea, which cause the hydrolysis of PMMA, may be responsible for this result. PMMA contains an ester group, which is easily hydrolyzed by acidic and basic content to produce carboxylate and alcohol. The carbonyl group's oxygen atom attaches to the proton (acidic hydrogen) in the first step of the reaction, which increases the carbon's electrophilicity. Next, the nucleophile (H2O) attaches, the alkoxy group departs, and carboxylic acid and alcohol are produced. This explanation is in agreement with Alla et al. [18]. Both Table 1 and Fig. 6 demonstrated that the impact of tea and coffee on hardness varied significantly. Coffee has a less significant impact on hardness than Pepsi. Coffee and tea, which are frequently regarded as super foods because of their antioxidant content, can erode teeth, but not as much as citrus juices, soda, energy drinks, and sports drinks. Black tea has an acidic content, yet drinking it only slightly and quickly lowers the pH at the surface of the teeth [14].

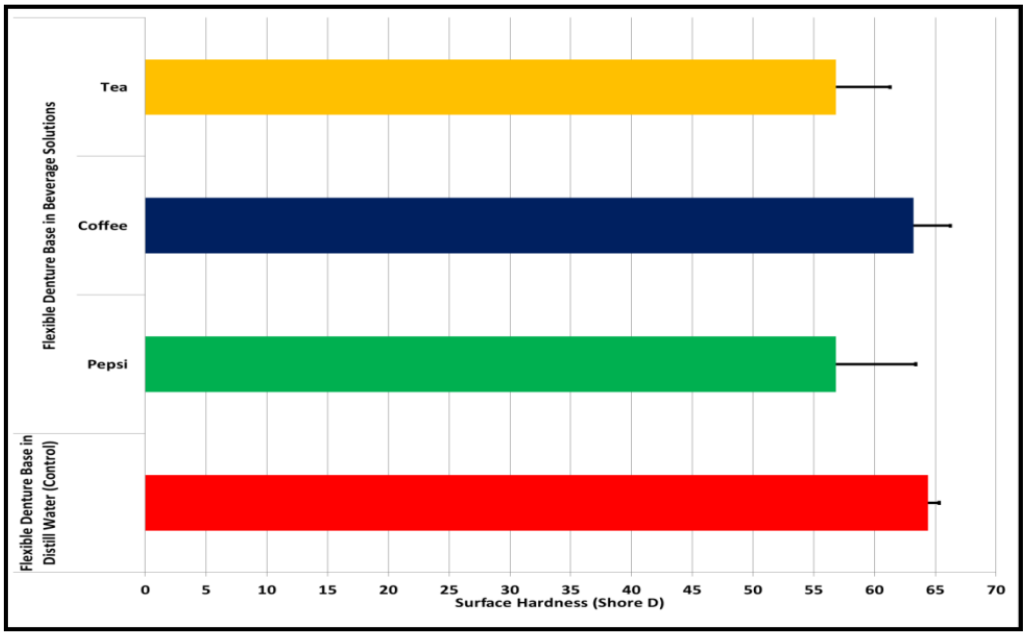

Fig. 6. Mean surface hardness test distribution among flexible specimens in distal water and specimens in the beverage solution

5. Conclusion

- Group A specimens submerged in distant water recorded the highest result for the microhardness test, whereas Group B and Group D reported the lowest mean values.
- The hardness of flexible denture base materials is lowered after 30 days of soaking in Pepsi and tea.

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