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Assessment of the surface hardness of high-impact polymethylmethacrylate following long-term dipping in clove oil solution

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Abstract:

Clove oil disinfects polymethylmethacrylate. Post-clove oil solution immersion high-impact polymethylmethacrylate surface hardness was examined. Thirty high-impact polymethylmethacrylate specimens were used and divided into control, 2% clove oil solution, and 6% clove oil solution groups. Shore-D tester measured surface hardness. Data was analyzed using the Shapiro-Wilk test, one-way ANOVA at 5% significance, using the SPSS software. The highest surface hardness mean was 6% (80.07), followed by 2% (79.96) and control (79.93). In this study, clove oil didn't affect surface hardness. 2% and 6% groups had similar surface hardness to the control group.

Keywords: clove oil, high-impact, polymer, polymethylmethacrylate, surface hardness.

Introduction:

Polymethylmethacrylate (PMMA) represents the most desirable polymer used for dentures because of its pleasing appearance, little water absorption, and low level of toxicity(Abd Alrazaq Y W and Khalaf B S, 2023, Abdulrazzaq Z A and Khalaf B S, 2023 and Noori Z S et al.,2023). Nevertheless, this substance remained feeble and incapable of enduring the forces applied during chewing, making it susceptible to breaking when exposed to collision(Mohammed S L and Farhan F A, 2024, Fatalla A A et al., 2018 and Al-Hiloh S A et al., 2016). High-impact PMMA was developed to resist fractures (Qanber, L M and Hamad T I, 2021).PMMA facilitates the accumulation of food and the proliferation of microorganisms. Hence, it is essential to clean dentures (Noori Z S et al., 2023, Kiesow A et al.,2016 and Al-Shammari S S et al.,2023). Immersion is suggested for elderly individuals who cannot clean dentures due to illness since it gently removes debris and eliminates microbes (Gornitsky M et al.,2002, Harrison Z et al.,2004 and Al-Jammali Z M,2021). Sodium hypochlorite is often used, although it may result in harm, staining of dentures, and irritation of the skin (Kumar M N et al.,2012 and

Nascimento M S,2003). Hydrogen peroxide has antimicrobial properties, but it has the undesirable effect of causing discoloration on dentures and reducing their flexural strength (Lee S Yet al.,1998 and Oliveira J C D et al.,2013).Research is now being conducted to explore the potential therapeutic use of essential oils. (Shah P A et al.,2023). Clove oil, known for its antibacterial and antifungal properties, is used in polymethyl methacrylate (PMMA) (Ullah M A et al.,2023, Adjal F et al.,2023 and Al-Irhayim, R N, 2011). The study examined the surface hardness of high-impact PMMA after being soaked in clove oil for an extended period.

Material and Method:

Specimen grouping:

Thirty specimens of the high-impact polymethylmethacrylate (PMMA) (Veracril® / Opti-cryl high impact, Newstetic, Colombia) were fabricated for this research. The collected specimens underwent surface hardness testing and were classified into three groups based on the concentration of clove oil utilized.

The first control group was immersed in distilled water for preservation.

The second group was immersed in a solution containing 2% clove oil.

The third group was immersed in a solution containing 6% clove oil.

The 2% and 6% groups were submerged for three minutes six times a day for one month. Following each immersion, a new solution was used, replicating six months of soaking. Each group had ten specimens.

General test specimen preparation:

The specimen's measurements were 35mm x 35mm x 6mm, as specified by the ISO standard 868 from 2003 (ISO 868,2003). Precise plastic designs were created using laser-cutting equipment. A mold was fabricated using a firm putty material called Ergamix® shore A 70, a laboratory-grade silicone produced by LASCOD in Italy(Neppelenbroek K H et al.,2005). The silicone's base and catalyst were mixed in a plastic container, as instructed by the manufacturer. Subsequently, the plastic designs were immersed in silicone and left to solidify. After the silicone had fully hardened, the excess material was trimmed off, and the mold containing the plastic patterns was removed from the plastic container. The type 4 dental stone (Zhermack®, Italy) was prepared according to the manufacturer's instructions, with a water/powder ratio of 25ml/100g. It was then inserted into the flask's bottom half coated with separating media (IZO-SOL, Zhermack, Italy). Subsequently, the mold and plastic design were inserted into the stone and left to solidify. After the stone setting, the entire surface was coated with a separating material, which included silicone, stone, and plastic patterns. Subsequently, the upper portion of the flask was placed on top of the lower portion, which was already filled with the newly prepared stone mixture. The flask was then sealed with its cover and undisturbed until the mixture solidified. Next, the two parts of the flask were detached, and the patterns were extracted, as seen in Figure 1.

Figure 1: A silicone mold for surface hardness after the plastic designs have been invested and removed.

Quantification and blending of high-impact PMMA constituents:

The quantities of polymer, monomer, and clove oil were determined using a digital balance of 0.001g for weighing powders and monomers and a micropipette for measuring liquids. Subsequently, the polymer and monomer were combined by applying a powder-to-liquid ratio of (2:1).

Packing:

The powdered material and liquid were mixed according to the manufacturer's guidelines. After the resin became plastic, it was inserted into the silicone mold in the flask's bottom section. A polyethylene layer was put between the outer layer of the material and the mold. The whole of the item, including its top part and a cover attached to the lower half, was pressed down inside a hydraulic press.

An initial compression was used to achieve a homogeneous dispersion of the material. Subsequently, a flask was extracted from the press to facilitate the elimination of surplus material. Subsequently, there was a progressive rise in pressure till it reached a maximum of 100 kg/cm^2. Subsequently, the flask is tightly sealed again, and a conclusive compression is executed at a pressure of 150 kg/cm^2 to ensure that the vertical dimension stays unaltered as per the specifications provided by the manufacturer. The flask was extracted from the press, placed into the clamp, and securely fastened.

High-impact PMMA polymerization process:

Following the company's guidelines, the flask and clamping were immersed in water for curing. Initially, the flask was immersed in chilled water, then elevated to 73°C and maintained at this temperature for 90 minutes.

Subsequently, the water temperature was elevated to 100°C for 30 minutes. Subsequently, the flask was transferred from the boiling water bath to the ambient air at 23°C for 30 minutes. Ultimately, the flask was submerged in chilled water at 23°C for 15 minutes.

Finishing along with polishing:

All specimens used for measuring surface hardness had been finished and had a polished and lustrous appearance, as seen in Figure 2.

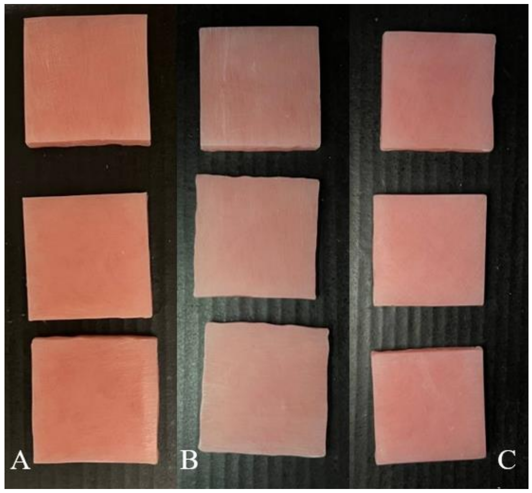

Figure 2: Some of the completed specimens used for assessing the hardness of the surface. A: Control group, B: 2% Group, and C: 6% Group.

Immersing the specimens in the water may reduce the amounts and duration of remaining chemical release and improve the mechanical properties of the PMMA. Before the inspection, the high-impact PMMA specimens were immersed in non-ionic water at 37 degrees Celsius for 48 hours to establish a standard state(Al-Shammari S S and Abdul-Ameer F M, 2023).

Preparation of a solution containing clove oil:

Two concentrations, 2% and 6% were chosen for immersion based on prior findings that revealed the efficient inhibition of particular mycotoxigenic molds and yeasts by 2% clove oil. The most positive effect was achieved after a three-minute immersion duration(Abidin Z Z et al.,2023). A surfactant (Tween 80/®Himedia/India) was used with the clove oil (100% pure clove oil/NOW®/U. S. A) to distribute the oil throughout the distilled water. The hydrophilic emulsifying ingredient, Tween 80, dissolved completely in the water-based phase. As a result, it was used to create emulsions of oil and water. Emulsions were prepared at 28 ± 5 ºC using magnetic stirring equipment (Digital LCD magnetic stirrer/HYCC®/China) operating at 300 revolutions per minute. Distilled water was incrementally added to the oil and tween 80 combination, with a volume ratio 1:1 (oil to tween 80). The mixture was then stirred for 10 minutes. The emulsions were kept at 28 ± 5 ºC to assess their short-term stability (De, H H V K N et al.,2023).

Immersion procedure:

After finishing and polishing, every specimen was cleaned by submerging them in distilled water to remove dust particles and other impurities. In the control group, specimens were conserved in a glass container filled with distilled water. On the other hand, the 2% and 6% groups were placed in glass containers containing newly made solutions of clove oil with concentrations of 2% and 6%, respectively.

The specimens were delicately manipulated utilizing a plastic tweezer and were immersed without any overlap since this might impact how much they were exposed to the clove oil solution. In the case of the 2% and 6% groups, a separate glass container filled with purified water was used to eliminate any remaining traces of clove oil after each submersion of the specimens. Subsequently, the specimens were allowed to undergo natural evaporation until the absence of visible moisture, and then they were submerged in the clove oil solution. The clove oil was replaced with a newly produced one following each immersion. The whole immersion process was conducted six times daily over one month, replicating six months of complete immersion.

Testing procedure:

Surface hardness test:

The test was conducted with a Shore D hardness instrument (Shore D durometer, China) following ISO 868 (ISO 868,2003).

The device consists of a spring-operated indenter with a diameter of 0.8 mm and a digital gauge ranging from 0 to 100 units. Each sample was subjected to five hardness tests, with a spacing of 6 mm between each measurement. The mean value of the measurements was estimated, as seen in Figure 3.

Figure 3: Device for measuring Shore D hardness

Result and Discussion:

Result:

Statistical analysis:

The surface hardness values of each specimen were assessed and summarized. The statistical program (SPSS) was used to examine each group's mean and standard deviation. The Shapiro-Wilk test was used to determine the data's normality, followed by a one-way analysis of variance (ANOVA) with a significance level of 0.05.

According to the results shown in Table 1, the results of the Shapiro-Wilk test indicated that surface hardness examined in the different groups followed a normal distribution.

Table 1 Test of normality of surface hardness utilizing the Shapiro-Wilk testing.

Variables	Groups	Shapiro-Wilk normality test		
		Statistic	*Df	*P value
Surface hardness	Control	0.9571	10	0.7520
	2% Clove oil	0.9449	10	0.6087
	6% Clove oil	0.8945	10	0.1907

*Df: Degrees of freedom. *P value: represents the probability of data's normality.

The group treated with 6% clove oil exhibited the highest average value of 80.07. Then, the group treated with 2% clove oil had an average value of 79.96. The control group, on the other hand, had the lowest average reading of 79.93. These results may be seen in Table 2 and Figure 4.

Table 2: The descriptive statistics for the surface hardness testing.

Groups	N	Mean	±Standard deviation	±Standard error	Minimum	Maximum
Control	10	79.93	1.110	0.3509	78.28	81.52
2% Clove oil	10	79.96	0.6820	0.2157	78.86	80.86
6% Clove oil	10	80.07	0.9339	0.2953	79.02	81.54

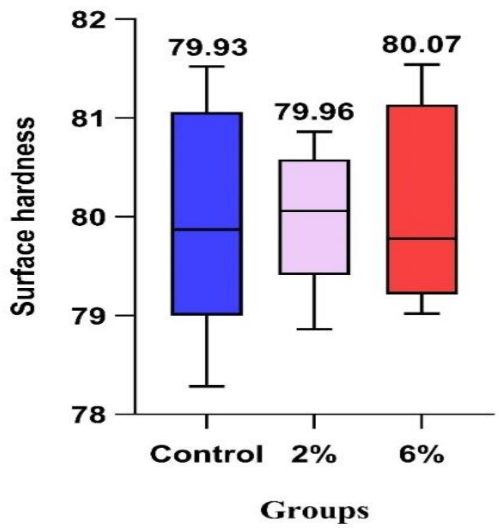

Figure 4: Boxplot chart of surface hardness testing

The one-way analysis of variance (ANOVA) was employed to compare the mean values of surface hardness across all the evaluated groups. The results (P value > 0.05) indicated that there were not any significant differences among the groups being studied, as shown in Table 3.

Table 3: One-way ANOVA of surface hardness test.

ANOVA table	Sum of Square	*Df	Mean Square	*F	*P value
Between groups	0.1143	2	0.05717	F (2, 27) = 0.06678	P=0.9356
Within groups	23.12	27	0.8562		
Total	23.23	29			

Df: the degree of freedom(the variability within and between groups). F: the ratio between the average square between groupings and the average square among groupings .*P value represents the chance of no difference in obtaining a result equal to or higher than what was observed.

Discussion:

High-impact PMMA can be cleaned and disinfected by submerging it in homemade solutions. However, these cleaning chemicals impact the polymeric material's characteristics (Jasim S A and Abass S M, 2021). Hence, this research examined the effect of dipping high-impact PMMA within a clove oil disinfection solution for an extended period on its surface hardness. No noticeable differences were seen when comparing the control group exposed to non-ionic water to groups immersed in 2% and 6% clove essential oil solutions for a long period.

The surface hardness of high-impact PMMA in the 2% and 6% groups remained almost identical to that of the control group. Because the strength of its cross-linking governs the surface hardness of PMMA, the polymeric structure may vary based on its type and composition, including colors, cross-linking agents, fillers, and fibers (Pereira C J et al., 2019). This study used a high-impact PMMA material and a cross-linking agent, significantly enhancing microhardness maintenance.

These results are consistent with those of Pereira et al., who discovered that the surface hardness of the heat-cured acrylic resin remained unchanged after being immersed in vinegar and hydrogen peroxide as alternative disinfecting solutions. In addition, our findings support the study findings of (Jasim S A and Abass S M, 2021), which observed that the outcomes of the surface hardness testing were unchanged after dipping the specimens in 5% or 10% $KAL(S0_4)_2$ disinfection solutions for sixty and one hundred eighty hours. However, our findings have a different perspective on the conclusions obtained by (Ozyilmaz O Y and Akin C, 2021), who discovered a decrease in the hardness of heat-polymerized PMMA when it was immersed in denture cleansers such as Corega, Protefix, Curaprox, and Perlodent. The reduction in hardness was seen regardless of the cleaner used.

Conclusion:

The present research showed that prolonged immersion did not influence the surface hardness of high-impact PMMA in 2% or 6% clove oil solutions, which means that the material's surface hardness was preserved.

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