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Research Article

Impact of Disinfectants on the Surface Integrity of Polycarbonate Denture Base Polymers

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ABSTRACT

Introduction: Dentists face numerous challenges in providing high-quality care to their patients, with one of the most significant being the selection of appropriate materials. These materials are crucial for creating prosthetic devices that not only function effectively but also meet aesthetic standards. Aims: to evaluate the effects of 2% hydrogen peroxide and 1% peracetic acid on the surface hardness and roughness of polycarbonate material.

Materials and methods: Polycarbonate specimens were submerged in solutions of hydrogen peroxide and peracetic acid (1% and 2%, respectively). A total of 30 specimens were produced and divided into three groups: control, 1% peracetic acid, and 2% hydrogen peroxide, with 10 specimens for each test (hardness and roughness). The specimens were submerged in disinfecting solutions for five minutes three times every day for 12 days. A one-way ANOVA was used for each material, followed by an independent t test to compare polycarbonate and polyamide.

Results: In this study, the hardness of polycarbonate (PC) was significantly affected by different disinfectants: control (86.671), 2% hydrogen peroxide (83.401), and 1% peracetic acid (80.631) ($p < 0.05$). Similarly, the surface roughness of PC differed significantly among groups: control (3.241), 2% hydrogen peroxide (3.912), and 1% peracetic acid (4.121) ($p < 0.05$). Tukey post-hoc analysis indicated significant roughness differences between all groups ($p < 0.05$).

Conclusions: It was concluded that the immersion of polycarbonate in 1% acetic acid and 2% hydrogen peroxide solutions can alter the surface properties of the injectable denture base materials.

KEYWORDS: Polycarbonate, Denture base, Vickers hardness, Surface roughness, Surface hardness

1. INTRODUCTION

Dentures are made from a variety of materials, and each of these materials influences the size of the denture base during production as well as many parameters pertinent to clinical use. These components include stability, support, retention, flexibility, impact resistance, surface roughness, and other characteristics. Denture base materials are classified into numerous categories and groups based on the production method, chemical structure, and processing procedures. [1]

Some thermoplastic polymers, such as PMMA, may be treated using a variety of techniques, including compression molding and injection molding. [2] However, the compression molding of PMMA is the most extensively used approach to creating acrylic denture bases, but the change in size and shrinkage of the denture base throughout the polymerization and the existence of residual monomers are the primary disadvantages of this method. [3] Given that the qualities of the denture can be altered not only by the

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material type used to produce the denture, but also by the processing techniques selected, new processing techniques were developed to overcome the limitation in conventional compression molded technique, such as injected molded technique, to improve dentures' efficiency and properties. [4]
Since its introduction in 1937, polymethyl methacrylate has remained the most widely favored material for denture fabrication.[5] In recent years, thermoplastic materials crafted through injection molding techniques had become popular for denture base fabrication due to their favorable qualities, which include having a higher degree of flexibility than heat-polymerizing base resins and the ability to help retain dentures by making use of the undercuts present in the design of the denture base around abutment teeth. [6]
In the 1950s, polyamide emerged as a suggested material for denture base construction. Polyamide is a crystalline polymer, whereas PMMA is amorphous. [7] The crystalline nature of polyamide contributes to its resistance to solvents, along with its notable attributes of elevated heat resistance and strong durability. However, this material is not without challenges. Issues such as water absorption, surface roughness, susceptibility to bacterial presence, warping, fading color, and challenges in achieving a polished finish have been reported. [8]
Crafted from high-quality lightweight plastic, polycarbonate is an amorphous polymer that displays occasional crystalline regions**.** Its translucent nature is coupled with exceptional mechanical properties, including remarkable resistance to impacts and structural stability. However, polycarbonate does come with certain property-related drawbacks. These include low tolerance to chemicals, restricted ability to withstand scratches, and a responsiveness to ultraviolet (UV) rays that initiates alterations in color. [9]
The ideal denture base material should be able to withstand masticatory forces, be easy to handle and disinfect, and be biocompatible with oral tissues. [10] For individuals utilizing fixed and partial removable dentures, ensuring denture hygiene, and preserving the well-being of oral mucosa holds significant importance. [11] Disinfection involves the application of chemical agents to eliminate or eradicate potentially infectious organisms, and this category encompasses heat-based techniques as well. Various mechanical and chemical methods have been employed to cleanse and disinfect the surfaces of dentures, removing accumulated microorganisms. [12] 1% Peracetic Acid and 2% Hydrogen Peroxide are among the chemicals utilized for this purpose. [13] Nevertheless, these measures have proven to have adverse effects on the structural integrity of the denture foundation. Sodium hypochlorite is an excellent disinfectant with excellent cleaning properties. The effectiveness of sodium hypochlorite in cleaning and disinfection operations is controlled by the amount of accessible chlorine and the PH of the disinfectant solution. [14, 15]

2. MATERIALS AND METHODS

2.1 Materials used in the study

The materials used in the study are the following:

1. Polycarbonate (Extra rigid polymer M10 XR, Deflex, Argentina. (Figure 2-1B).
2. Isodent gypsum separating solution (Spofa Dental Czechoslovakian Europe).
3. Dental stone (Zermach, EXTRA HARD HIGH DENSITY DIESTONE, Spain).
4. Peracetic acid 1% (LaMotte, USA).
5. Hydrogen Peroxide 2% (Clorox Professional Products Company, USA).

2.2 Specimens grouping

Thirty specimens were prepared, 10 specimens were control specimens kept in distilled water as control, 10 were immersed in Peracetic Acid, and 10 immersed in hydrogen peroxide.

2.3 Preparation of acrylic pattern

The acrylic pattern measurements were developed using computer software (Auto CAD, 2015) and then made using a laser cutting equipment. Clear acrylic sheets (Glass-look acrylic, Clairvauxles Lacsrance, France) were cut into bar-shaped specimens with dimensions of 65mm x 10mm x 2.5 ± 0.1mm for surface roughness and Vickers microhardness tests (Figure 1).

Figure 1: Plastic pattern cut using CNC

2.4 Mold preparation for Polycarbonate

Separating media was used to cover the metallic dental flask components, and then a stone mixture was prepared according to the manufacturer's instructions, using 100 g/25ml (powder/water) to fill the lower half of the flask. Meanwhile, it was aggressively vibrated to eliminate air bubbles. The plastic designs were then placed, taking care not to entirely embed them in the tooth stone so that they could be removed after the flasking treatment was done. Wax tubes (sprue) were attached to the plastic pattern to assist material injection (Figure 2).

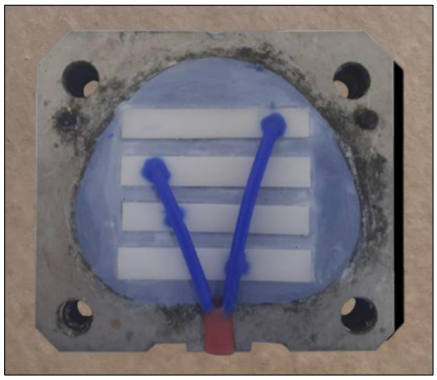

Figure 2: Wax sprue attached

Both the stone surface and the plastic patterns were covered with separating medium and allowed to dry after the dental stone was fully set. Since assembling the flask's equivalent, the flask was filled by pouring another mix of stone and vibrating it again. The flask's upper lid was mounted, and the flask was tightly clamped until the stone was fully set. Then, the flask placed in boiled water bath for wax elimination.

2.5 Injecting, packing, and finishing of the test specimens.

Polycarbonate capsules were placed in the automatic programmable device DEFLEX MAD and injected into the flask according to manufacturer's instruction as following: Polycarbonate was injected under pressure (5-7 Bar) and subjected to heat (305°C ± 10°C) for a duration of 15 minutes. The injection process was executed using an automatic programmable device with the following specifications: digital control, preset programs, user-defined programs, and a pressure gauge (manometer). Before commencing the injection, the pressure for injection was assessed to align with procedural requirements. Similarly, preheating temperature and duration were verified in accordance with the manufacturer's instructions. The appropriate injection material cartridge was selected. To facilitate the process, a Vaseline-based lubricant was applied to the closed end of the cartridge. Subsequently, the cartridge was placed into either of the two heating cylinders, directed towards the flask chamber. Any excess lubricant on the heating cylinder's edge was removed using absorbent paper. The preheating process was initiated, and an audible signal indicated the end of the preheating duration as chosen. Once the two halves of the flask were assembled and secured with screws, the flask was positioned within the injecting unit and fixed in place. The opening of the flask was aligned directly with the cartridge and the heating cylinder. The injection process was initiated by pressing the start key on the control panel, activating the injection procedure. The setting contraction was compensated for by automatically keeping the pressure constant for (1) minute. The cylinder was then moved about 3 to 4 mm away from the flask so that the cartridge could be separated. Subsequently, the flask was taken out, and the utilized cartridge was automatically released by pressing the evacuation button. To ensure the attainment of optimal material quality, the flask was subjected to gradual cooling over a period of approximately 8 to 9 hours. Following the cooling process, the screws securing the flask were loosened, and the two halves of the flask were carefully separated. This allowed for the removal of the specimens from the molds (Fig. 3).

Figure 3: Specimens after de-flasking

2.6 Finishing and polishing

After the process of removing the specimens from the molds (de-flasking), any excess material was carefully removed to achieve a clean finish. The specimens made from polycarbonate and Polyamide were separated, and the sprue was eliminated using a metal disk for cutting. Subsequently, each individual specimen underwent finishing using specialized plastic burs tailored for this purpose. The removal of excess material was performed with an acrylic bur. Following this, all specimens underwent a finishing process involving sandpaper with a grain size of 120. To prevent overheating, the specimens were periodically cooled by immersing them in a rubber bowl filled with distilled water. This cooling process involved a 15-second interval of finishing followed by a 15-second immersion in water. The completed specimens of each test group were collected and housed within plastic containers. These containers were filled with distilled water and subsequently placed within an incubator set at 37°C for a period of 48 hours, adhering to the specifications outlined in the ADA 1999 standard**.** The purpose of this incubation was to eliminate any residual byproducts from the specimens.

2.7 Disinfection procedure

Each specimen will be immersed in the disinfecting solutions for 5 minutes, 30 times a day for 12 days to simulate 1-year interval and after each immersion the specimen will be taken out and rinsed with running water and dried with absorbent paper and the procedure of immersion will be repeated simulating the patient denture cleaning [16]

2.8 Vickers hardness and surface roughness tests

The Vickers hardness test was performed with (laryee hvs-5Manufacturing Limited, Bei-jing, China), specimens were submitted to a 25-g load for 30 second. Three places were utilized on the specimen. One in the center and two on either end. The average of three readings was calculated (Figure 4).

Figure 4: Vickers hardness tester

Surface roughness test was performed using a profilometer (Figure 5). This tester contains a diamond sensible needle (stylus) used to track the irregularities on the surface. Using a stylus, the surface of the specimen is engaged at three distinct points across its surface to obtain three readings from each specimen. The specimen is positioned on a stable and firm surface, and the stylus is allowed to make contact with the first point. Subsequently, the stylus is moved along the surface for a distance of 11 mm. The readings are automatically displayed on a digital scale as they are generated. The average of the three readings is then calculated to determine the roughness value of the specimen.

Figure 5: Surface roughness testing Profilometer

2.9 Statistical analysis

An ANOVA test was used to compare the mean values of the tested groups (one-way analysis of variance). Levene's test was used to assess the homogeneity of variance in each test. To see if there was a significant difference between the groups, Tukey's post-hoc test (multiple comparisons) was used.

3. RESULTS AND DISCUSSION

3.1 Surface hardness

Hardness refers to a material's capacity to withstand wear and abrasion from adjacent dental structures. It serves as an indicator of a material's resilience and its ability to resist damage. The concept of hardness is frequently employed to investigate various factors that impact the extent of resin conversion. Because of the simplicity of the process, it is possible to characterize the mechanical properties of a polymer. In addition to the availability of the specimen preparation and test procedure equipment. [17] This experiment used a Vickers microhardness tester, which is appropriate for determining the hardness of denture bases. The Vickers microhardness tester eliminates the problem of elastic recovery due to its design. The application of a technology that directly measures the depth of the loaded indentation by a screen that displays the number of them. [18]

Following immersion, a statistically significant reduction in surface hardness was observed in the Polycarbonate specimens when compared to the control groups **(**Table 1). This shift can be attributable to the deterioration caused by the amounts of Hydrogen Peroxide and Peracetic Acid. Following immersion, the damage sustained by the material matrix accelerates the process of water transport, increasing water absorption. [19] The presence of oxygen in carbonate groups (CO_3) in polycarbonate specimens makes them susceptible to water absorption. As water molecules gather around the polymer chains of polycarbonate, the polymer's structure becomes deformed and more open, resulting in greater free volume. This increased diffusion of water molecules into the polymers has a plasticizing effect, progressively relaxing the polymer chains and producing a decrease in hardness. [20]

Table 1: Descriptive statistics, one way ANOVA and Tuckey test of hardness

Polycarbonate PC			Post-hoc test
Groups	**Mean PC**	**ANOVA**	**P value**
Control (A)	**86.671**	**0.000 H. S**	**A and B 0.015 H. S**
2% Hydrogen Peroxide (B)	**83.401**		**A and C 0.000 H. S**
1% Peracetic Acid (C)	**80.631**		**B and C 0.018 H. S**
Levene's test P-value: 0.192			

3.2 Surface roughness

The profilometer device was used in this study which was reported to be an excellent device for studying the surface roughness of restorative materials and giving measurements that can be evaluated and compared. Surface texture plays a crucial role as it can lead to the accumulation of bacteria on uneven denture surfaces, influencing oral well-being. [21] The coarseness of denture surfaces is influenced by factors such as material properties, polishing methods, and the proficiency of the practitioner. [22] All resin materials should aim for a smooth, scratch-free surface, because an increase in surface roughness can decrease denture esthetics, while a decrease in surface roughness can improve denture esthetics, Surface roughness helps to prevent bacterial build-up and plaque formation accumulation. [23]

The results revealed an increase in surface roughness of polycarbonate specimens after immersion in disinfecting solutions (Table 2).

Table 2: Descriptive statistics, one way ANOVA and Tuckey test of roughness

Polycarbonate			Post-hoc test
Groups PC	**Mean PC**	**ANOVA**	**P value**
Control(A)	**3.241**	**0.000 H. S**	**A and B 0.022 H. S**
2% Hydrogen Peroxide (B)	**3.912**		**A and C 0.000 H. S**
1% Peracetic Acid (C)	**4.121**		**B and C 0.004 H. S**
Levene's test P-value: 0.113			

The observed increase in surface roughness in the presence of hydrogen peroxide and peracetic acid is due to their induced increase in hydrophilicity and the existence of ester linkages in the material. Water can degrade ester bonds, especially under alkaline circumstances. This degradation process may include the hydrolysis of a polyester chain into two sub-chains with carboxyl and hydroxyl terminations. [24]

Increase the number of the molecular chain per unit cross section and increase in the junction number will cause increase in surface roughness [25]**,** this agrees with Wang *et al.,* In 2019. [26] An alternative explanation suggests that the observed increase could stem from the phenomenon where a polymer, upon exposure to a solution, undergoes hydrolytic breakdown. This breakdown is a consequence of the chemical interaction occurring between the

solution and the organic matrix present within the interstitial spaces between the polymer chains. [27, 28]

4. CONCLUSIONS

The study investigated how sodium hypochlorite and hydrogen peroxide affected surface hardness and roughness via hydrophilicity and ester bond interactions. This study advances our understanding of surface characteristics in dental materials and their consequences for denture aesthetics and cleanliness.

Conflict of interest

None

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