ORIGINAL ARTICLE

Wettability, UV Absorption, and SEM Investigation of PMMA after Immersion in Ozone Water

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Abstract

Purpose: Denture stomatitis, poor oral health, and angular cheilitis can all result from bacterial and fungal colonization. As a result, denture cleaners have been suggested to preserve the longevity of partially removable dentures and the health of the oral mucosa. The purpose of the present study was to investigate the impact of ozone water on Polymethyl Methacrylate (PMMA) by studying wettability, Ultraviolet (UV) absorption, and surface topography following soaking for 10 and 20 minutes at a 2 mg/l concentration.

Materials and Methods: A sixty-disc-shaped sample of polymethacrylate material (Ivoclar Vivadent) was fabricated for the wettability and UV absorption tests, and three bar-shaped samples of polymethacrylate material (Ivoclar Vivadent) were fabricated for the surface topography. Three groups were created: the first was the control group (immersion of samples in distal water). Second group (immersion of samples in 2 mg/l of ozone water solution for 10 min), and third group (immersion of samples in 2 mg/l of ozone water solution for 20 min). The contact angle (a wettability parameter) on the surfaces of the samples was measured after each storage period. The UV absorption test was assessed using a spectrophotometer; ANOVA was used to perform statistical analysis on the data at level 0.0.5; and surface topography was evaluated using Scanning Electron Microscopy (SEM).

Results: Based on the findings of this research, there was no statistically significant difference between the experimental and control groups when testing wettability and UV absorption. There is no change in surface topography when assessed by SEM.

Conclusion: This research concluded that the samples prepared from PMMA material can be safely soaked in an ozone water solution without compromising their properties.

Keywords: Polymethyl Methacrylate; Ozone Generator; Wettability; Spectrophotometer; Scanning Electron Microscopy.

DOI:

1. Introduction

Polymethyl Methacrylate (PMMA) has been the best material for denture bases since 1930 [1]. PMMA is popular in prosthetic dentistry due to its color similarity to oral tissues, low price, and simplicity of processing and equipment usage. Despite this, PMMA is still not an ideal denture base material due to numerous drawbacks, such as biofilm formation on its surface and vulnerability to microbial colonization. This makes the denture a potential source of infection because it is prone to microbes [2, 3].

Wettability is a crucial criterion for a denture base. The wettability of liquid and solid surfaces plays a significant role in adhesion (the important forces required to retain the denture). Wettability is determined by assessing the contact angles between solid surface and liquid. Lower contact angles tend to wet the surface better, while zero contact angles result in total wetting [4]. Wettability has a significant impact on denture retention because it enables saliva to spread across the denture surface smoothly and quickly, which in turn improves denture retention. Moreover, by acting as a cleaning agent, wettability helps minimize the growth of candida on the denture surface and improves patient comfort [5].

PMMA is optical clarity acrylic resin. PMMA changes its appearance when subject to ultraviolet radiation and hot weather. Due to chain scission in the polymer structure, fogging and cracks occur. The quantity of energy absorbed by PMMA determines the scission [6]. A cross-linking reaction develops between the ester side groups in PMMA polymer molecules at low irradiation dosages. The side-chain breakdown from the main polymer chain occurs with a moderate irradiation dosage, resulting in mechanical densification of the polymeric material due to van der Waals forces and an enhancement in some optical characteristics. While polymer main chain scission occurs at high irradiation doses, followed by total polymer defragmentation [7, 8].

Three oxygen atoms combine to form the natural gas known as ozone (O_3) (particle size: 10 microns or less, CAS number: 10028-15-6). It can be found in the stratosphere as a gas in concentrations ranging from 1 to 10 ppm or created using ozone generators. Ozone exists in gaseous and aqueous phases; ozone decomposes quickly into O_2 and OH radicals in aqueous solutions. It is a powerful antibacterial agent that kills over 99% of fungi, bacteria, and viruses [9] .Recent research findings suggest that the ozonated water created by a home ozone generator is a simple and low-cost solution for disinfecting the acrylic resin used in denture bases without damaging some properties [10]. This study aimed to assess the effect of ozone water on the properties of PMMA regarding wettability, UV absorption, and surface topography.

2. Materials and Methods

2.1. Pilot Study

A pilot study was done to establish the most suitable time for the immersion of PMMA samples. Different times of ozone exposure were employed: 10 min, 20 min, and 30 min. The safest times chosen for immersion are 10 and 20 minutes.

2.2. Preparation of Samples

Plastic disc patterns with dimensions of 50 mm and 0.5 mm in thickness for wettability and UV absorption tests, and bar shape with (30 x 15 x 2.5) mm in length, width, and thickness, respectively, for surface topography test. PMMA material (Ivoclar Vivadent, purity: >90%, particle size: 48-micron, CAS number: 9011-14-7, Liechtenstein) was applied in powder-liquid form. Following the manufacturer's directions, the PMMA was mixed and put into the stone mould. According to the standard polymerization protocol of Ivoclar Vivadent AG, the flask was placed in the water bath for 7 hours at 70 °C, the water was heated again until it reached 100 °C, and the flask was kept at that temperature for 45 minutes. The flask halves were separated after they had set. After polymerization, all specimens were finished with sharp scissors and polished with a 1000-grit, silicone polishing bur under continuous water until a glossy surface was obtained [11].

2.3. Samples Grouping

Group (C): Immersion of samples in distal water.

Group (OZ-10): Immersion of samples in ozone water at a concentration of 2 mg/l for 10 minutes.

Group (OZ-20): Immersion of samples in ozone water at a concentration of 2 mg/l for 20 minutes.

2.4. Preparation of Ozone Water

The ozonated water was freshly prepared by the ozone gas generating device (Multifunctional ozonize and Fruit and Vegetable Detoxification Washer, China). The ozone generator was operated according to the manufacturer's recommendations. This machine can perform numerous sterilization and disinfection procedures with time options ranging from zero to thirty minutes. The ozone gas generated by this machine has been introduced into a 1-liter volume of Deionized Water (DEW) for 30 minutes post-operative machine. The dissolved ozone concentration in the water was determined using a portable dissolved ozone meter (CS6930 dissolved ozone electrode, China). After preparation, the acrylic samples were soaked in ozone water for 10 and 20 minutes.

2.5. Wettability Test

The contact angle was measured using the sessile drop method. A sample stage that can be modified, an LED light source, and a video camera are all part of the photographic setup. A syringe clamp and a metal housing for the motorized syringe are also included. A tiny needle was used to place a single drop of distilled water (about 10 µl volume) on the material's surface being analyzed. Then, a computerized digital camera was used to take a picture. The pictures were taken 30 seconds after the drop was positioned on the ground. The software then evaluated the images to get the contact angle [12].

2.6. UV Absorption Test

A UV-visible spectrophotometer (Shimadzu, Japan 1900) was employed to measure the amount of UV light absorbed by samples as a functional wavelength. ISO 21348 classifies ultraviolet light into three groups: UV-A (315-400 nm), UV-B (280-315nm), and UV-C (100-280 nm) [13]. The radiation is emitted from a radiation source, such as a tungsten filament or Xenon arc, which illuminates the samples. The samples in the disk shape were placed above the light source and exposed to light at the spectral range of 200-400nm. The light reflected by the sample enters the monochromator and is detected by the detector. After that, the readings of the absorbed light were recorded [14].

2.7. SEM Analysis

A scanning electron microscope (Axia Chemi SEM, FEI company, Netherlands) was used to examine the impact of the ozone water on the surface topography of PMMA. A sample number (n = 1) was used in each study group. Because the specimens to be magnified may have some conductivity and thus become charged, they are coated with a platinum or gold layer to prevent charging and maximize secondary emissions [15].

2.8. Statistical Analysis

Statistical Package for Social Sciences (SPSS, version 25) and Microsoft Office Excel were used for statistical analysis. One-way ANOVA was used for comparisons between the groups. The p-value ($p<0.05$) was considered statistically significant.

3. Results

3.1. Wettability Test

According to Figure 1, the results of this test showed that the control group (C) had the highest mean value of static contact angle (73.34), indicating the least wettability, followed by the experimental group (OZ-10) with (71.48), and then the group (OZ-20) had the lowest mean value (70.51).

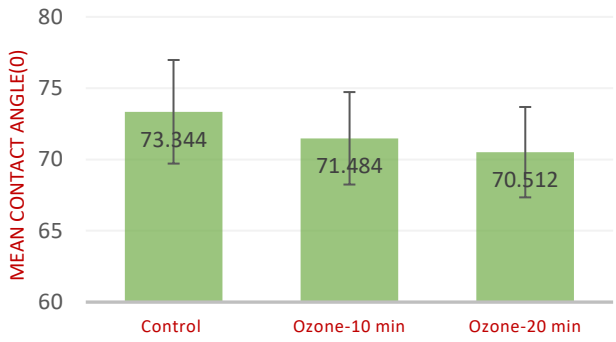

Figure 1. Bar char of wettability test

Table 1 represents One-way statistical analysis (ANOVA) for the wettability test, which revealed no significant differences between the experimental and control groups.

Table 1. Statistical test of wettability among groups using One Way Analysis of Variance (ANOVA)

	Sum of square	DF	Mean square	F	P-Value	Sig
Between groups	41.415	2	20.708	1.84	0.178	No sig
Within groups	303.678	27	11.247			
Total	345.093	29				

*No sig.: Non-significant

3.2. UV Absorption Test

PMMA is transparent polymers that exhibit minimal absorption of UV radiation in their original, unaltered forms. As seen in Figure 2, the UV-absorbing characteristics become apparent when the polymers are exposed to the electron beam.

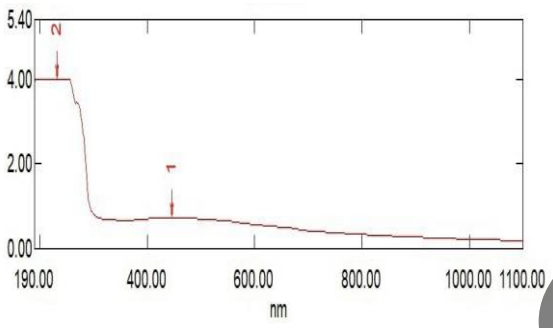

Figure 2. Spectra of UV-vis absorption of PMMA

In Figure 3, The UV-visible absorption spectra indicate that PMMA exhibits a notably higher absorption of UV radiation after immersion in ozone water with (0.00195nm) for (OZ-10 min) and (OZ-20 min) while (0.0018 nm) for control groups.

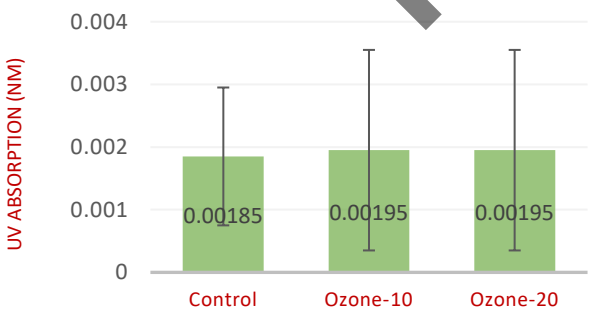

Figure 3. Bar char of UV absorption test

Statistically, Table 2 displays a one-way statistical analysis (ANOVA) of the UV absorption test that revealed no significant differences between the experimental and control groups.

3.3. SEM Test

The change in surface topography between experimental groups (OZ-10 min and OZ-20 min) and control groups (C) was evaluated using SEM. As depicted in Figures 4, 5, and 6, the findings of the photomicrograph show a good distribution of PMMA particles after immersion in ozone water for 10 and 20 minutes.

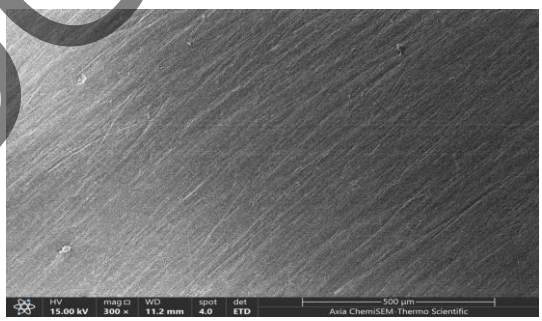

Figure 4. SEM of Control group

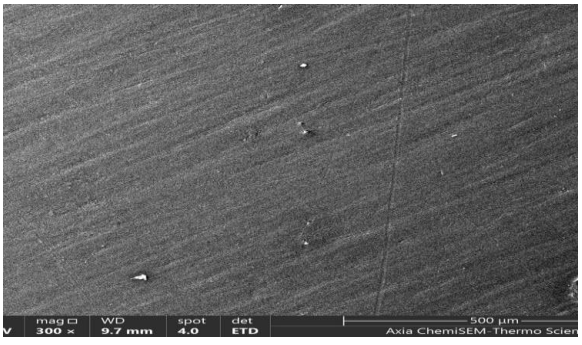

Figure 5. SEM of PMMA sample after immersion in ozone water for 10 min

Table 2. Statistical test of UV absorption among groups using One Way Analysis of Variance (ANOVA)

	Sum of square	DF	Mean square	P-Value	Sig
Between groups	6.67	2	3.33	0.2	No
Within groups	0.00005	27	2.05		
Total	6.21	29			

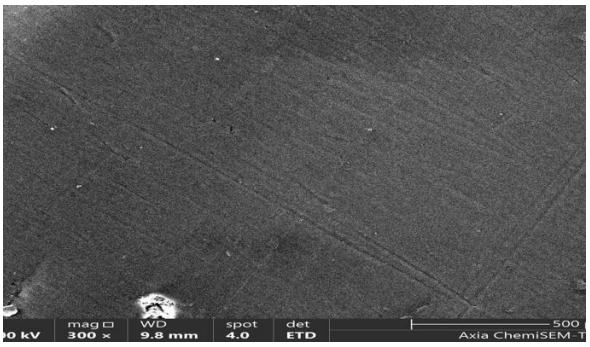

Figure 6. SEM of PMMA sample after immersion in ozone water for 10 min

4. Discussion

Most people who wear dentures struggle to keep them clean and almost always have poor oral hygiene. The primary contributing cause of illnesses of the oral mucosal tissues is unclean dentures. Maintaining proper oral hygiene and the cleanliness of dentures in edentulous people is critical for optimal health, especially in older people. Ozone is used as a substitute disinfectant in many different fields of dentistry, including restorative dentistry, endodontics, surgery, and prosthodontics, because of its high antibacterial action and lack of drug resistance [16].

In this study, two different periods of immersion and one concentration were employed, and some properties of PMMA between tested groups were compared, including wettability, UV absorption, and surface topography. The hypothesis test includes (a) that there is no difference between PMMA and ozone water. (b) that there is a difference between PMMA and ozone water. According to the result obtained, the first hypothesis was accepted.

In this investigation, the estimated mean contact angles of PMMA samples were 71.40 and 70.50 for the experimental and 73.30 for the control groups. According to research by Zissis *et al.*, the equilibrium contact angles of several acrylic denture base materials ranged from 63.9 to 81.0°. All contact angles acquired in this study may match the findings of the previous study [17]; this could be related to the homogenous surface of PMMA (Ivoclar Vivadent) used in this study, which agrees with Sharma and Chitre [18].

According to Alpana *et al.*, the PMMA material can be immersed in ozone water without compromising surface roughness [19]. This plays a significant role in the equilibrium of the contact angle because there is a direct relation between surface roughness and wettability, as indicated by Kubiak *et al.*, and Zelazinski *et al.*, [20, 21].

Polished surfaces of samples seemed to be a factor in the equilibrium of contact angle in this study; this agrees with Nishioka, who observed that wettability improved when samples were polished [22]. At the same time, this result disagrees with Abdulkadir, who discovered that unpolished surfaces' wettability was superior to polished surfaces [23].

The short duration of immersion may be another factor in this outcome because of the surface energy associated with the duration of treatment. At the same time, higher surface energy plays a significant role in good wettability. This agrees with Sipahi *et al.*, who state that the long immersion time will reduce the surface energy of the sample. This decrease has an adverse effect on wettability by increasing the contact angle with the water droplet [24].

The outcome of this research is generally consistent with Alamen *et al.*, who found that after 24 hours of incubation in distal water, the 2.5% and 1.5% coconut oil groups had lower mean values of contact angle (good wetting) than the control group [25]. Our result also concurs with Al Nema, who found that PMMA material had superior wettability than visible light-cured resin after being treated with human and artificial saliva [26]. However, this result disagrees with Abed's research, which claimed that PMMA immersed in 100 ppm and 200 ppm electrolyzed water significantly differed from PMMA immersed in distal water [27].

The ultraviolet region of the electromagnetic spectrum is between 40-400 nm. The result of the absorption of UV by PMMA samples after immersion in ozone water may be related to the presence of π electron (π electron is the electron that contains a double bond or triple bond) and a heteroatom (a heteroatom is an atom that contains an unshared pair of electrons such as oxygen (purity: 85-99% Particle size: 0.229nm, CAS number: 7782-44-7), nitrogen (purity: 99.998%, particle size: 0.305nm, CAS number: 7727-37-9, and sulfur (purity: 99.999%, particle size: 1 to 20 µm, CAS number: 7704-34-9), as shown in Figure 7, which illustrates the chemical formula of ozone.

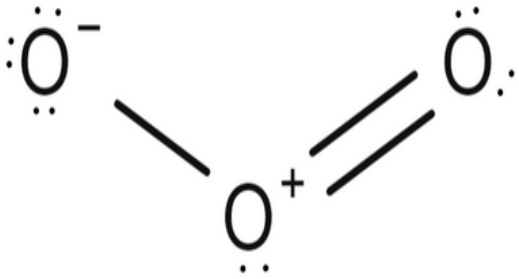

Figure 7. Chemical formula of ozone

A change in the electronic state of the molecules (π electrons and oxygen atoms) in the samples occurs when the samples absorb light in the ultraviolet area. The UV light that supplied the energy will encourage π electrons and (O) from states of low energy (unoccupied level) to states of higher energy (occupied level). This refers to an electronic transition [28]. The electron transition of ozone includes.

- σ to σ*
- n to σ*
- n to π*
- π to π*

Furthermore, absorption will occur in the UV area because there is π to π* transition type since this transition requires less energy than other types of transitions. This agrees with Skoog *et al.*, who state that the π to π* transition requires less energy and at a longer wavelength when compared with the transitions of σ to σ*, n to σ*, and n to π* which require more energy and do not exhibit strong absorption in the UV region [29].

Examining surface topography by SEM was done under 300X for all tested groups (control, ozone water), as shown in Figure 4, 5, and 6. The surface morphology of samples did not change after immersion in ozone water; this agrees with Tricarico, who used ozone water for disinfection and observed no change in the component surfaces of dental units when compared with control groups [30].

When PMMA samples absorb UV light at 200-400nm, Active oxygen oxidizes the PMMA surface. Oxygen molecules and ozone molecules can extract hydrogen atoms from the polymer chains. As a result, a carboxyl group is produced on the PMMA surface, enhancing its hydrophilic properties [31]. The roughness of PMMA will decrease with the improvement of hydrophilic properties, leading to a good distribution of PMMA particles after immersion in ozone water.

Resistance of PMMA to surface change may be another reason for the uniform distribution of PMMA particles after immersion in ozone water; this agrees with [32]. Even though there was no earlier study investigating the effect of ozone water on the surface topography of PMMA material, it was unable to compare the findings of this investigation with those of earlier similar studies. The outcomes of this study agree with Yun *et al.*, who stated that there was no change in the surface of PMMA when compared between distal water, sodium hypochlorite, and alkaline peroxide cleansers [33]. However, contrary to Pereira-Cenci *et al.*, when employing sodium perborate and 0.5% NaOCl as disinfection for PMMA, SEM examination revealed that the surface materials suffered more damage [34].

5. Conclusion

A variety of microorganisms frequently colonize dentures. Plaque buildup on the surface of the denture can cause denture stomatitis; this is a common occurrence in clinical practice. Therefore, it is essential to implement effective denture plaque control measures to prevent the occurrence of such results without compromising the properties of the denture. One effective approach for achieving this objective involves utilizing ozone water as a denture cleaning agent due to scientific research demonstrating that ozone could be an effective therapeutic agent in dentistry, and ozone water has been more convenient and cost-effective when compared to other chemical cleaners. Within the limitation of this study because of the low sample size, this study concluded that PMMA could be safely immersed in a 2 mg/L ozonated water solution for 10 and 20 minutes without changing wettability assessed by sessile drops, UV absorption that was measured by spectrophotometer and surface topography that examined by SEM. The reader should be informed that in vitro testing cannot correctly predict clinical outcomes and that more clinical research is needed to establish clear results.

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