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Effect of Gaseous Ozone on Surface Hardness and Surface Roughness of Heat Cure Acrylic Resin

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Abstract

Aims: to assess the effects of gaseous ozone and microwave exposure (as a positive control) on surface hardness and surface roughness of heat cure acrylic resin. **Materials and Methods:** A total of 60 samples of heat-cured acrylic resin were prepared, and divided into three subgroups, control, microwave radiation (positive control), and gaseous ozone. Surface hardness and surface roughness were evaluated. At a level of significance of 5%, data were assessed using one-way ANOVA and Tukey's post hoc test. **Results:** Surface hardness and roughness were significantly different among groups. ($p <0.001$). Significant differences were identified by the post hoc test between all multiple groups ($p <0.001$). **Conclusions:** It is possible to conclude that gaseous ozone exposure improves the surface hardness of heat-cure acrylic resin.

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تأثير غاز الاوزون على صــلادة الســطح و خشــونة الســطح للراتنج الاكريلي المعالج حرارياً

الملخص

الأهداف: تقييم تأثير غاز الأوزون واشعة المايكرويف (كمجموعة تحكم إيجابية) على صلادة السطح وخشونة السطح لمادة الراتنج الاكريليكي المعالج بالحرارة. **المواد وطرائق العمل:** تم تحضير ٦٠ عينة من راتنج الاكريلك المعالج بالحرارة. ثم تم تقسيم العينات الى ثلاث مجاميع، مجموعة التحكم ومجموعتين أخيرتين تم تعريض احداهما الى اشعاع المايكروويف (كمجموعة تحكم إيجابية) ومرة الى غاز الاوزون على التوالي. تم تحليل البيانات باستخدام اختبار تحليل التباين احادي الاتجاه واختبار توكي. **النتائج:** كانت صلادة وخشونة السطح بعد التعريض لغاز الاوزون ذات تأثير معنوي بالمقارنة مع المجاميع الاخرى. **الاستنتاجات:** مع حدود الدراسة، يمكن الاستنتاج بأن غاز الأوزون له القابلية على تحسين صلادة سطح الراتنج الاكريليكي المعالج حراريا.

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INTRODUCTION

In dentistry, for denture base applications, poly methyl methacrylate (PMMA) is the most widely used polymer [(1)]. because of its low cost, easy manipulation, and convenience in repair [(2)]. Denture cleaning is an essential component of dental hygiene because dentures provide a favorable environment for bacterial, fungal, viral, and other microorganisms [(3)]. To minimize cross-contamination and preserve healthy oral mucosa, the decontamination procedure must be carried out in a way that inactivates bacteria without negatively impacting the acrylic resins [(4)].

There are a variety of uses for microwave radiation, in dentistry, it can be used to sterilize removable dentures [(5)]. Fortes et al. investigated the effects of exposure to microwave radiation at high power for one minute on flexural strength and surface hardness is safe for cleaning dentures with preserving the physical-mechanical acrylic resin characteristics without causing damage. [(6)].

Three oxygen atoms make up the naturally occurring compound known as ozone (triatomic oxygen or trioxygen). It can be created by ozone generators (By applying high-voltage electricity to a gap (tube) containing oxygen, the high-voltage electricity causes the oxygen to recombine, resulting in the creation of ozone) [(7)]. As the following reaction:

$$3O_2 \rightarrow 2O_3$$

Or found as a gas in the stratosphere at a concentration of 1 to 10 ppm., the gaseous and aqueous phases of ozone had a potent antibacterial activity that was effective against viruses, bacteria, fungi, and protozoa [(8)]. One of the effective methods for sterilizing prosthetics is to use ozone as a disinfectant for dentures [(9)]. Ozone also breaks down quickly into O2 and OH radicals in aqueous solutions [(10)]. These characteristics make ozone a crucial therapeutic agent for inflammatory and infectious diseases.

This research was designed to study the influence of gaseous ozone on heat-cure acrylic resins' surface hardness and surface roughness.

MATERIALS AND METHODS

Ethical Statement:

The board of the research ethics committee approved the current study (University of Baghdad Dentistry, College, reference No. 669222).

Samples Preparation:

Sixty specimens of 65x10x2.5mm heat-cured acrylic resin were made, and by immersing the flask in a water bath, they were polymerized. The flask was placed in the water bath with cold water, then, the temper up to 70 C^o within 30 min. and kept the temperature on 70 C^o during the next 30 min., increase the temperature up to 100 C^o for 30 min., and kept temperature on 100 C^o for further 30 min. (Total polymerization time is 2 hours) according to manufactural instructions.

After the curing cycle ended, allow the flask to reach the temperature of the room. before being de-flasked and having the acrylic samples removed.

Using acrylic and stone burs with a prosthetic engine and continuous water cooling to prevent overheating and deformation, all acrylic specimens were polished to eliminate excess materials, except for those used for the surface roughness test. The polishing procedure was carried out with rouge in a dental lathe system running at 1500 rpm and utilizing constant water cooling until the specimens' surfaces became glossy. Before each test, the dimensions of each specimen were measured using a digital vernier.

Samples Grouping:

Specimens are divided into 3 main groups:

- Group I (as a control): 20 specimens immersed in distilled water.
- Group II (as a positive control): 20 specimens exposed to microwave radiation.
- Group III: 20 specimens exposed to gaseous ozone.

Microwave exposure:

In which specimens were separately placed in a distilled water beaker of 200 ml at room temperature (21° C±1) in a microwave oven with an output of 650W (2450 MHz) for 6 minutes, then also immersed in distilled water [11].

Gaseous ozone exposure:

In which the specimens were exposed to gaseous ozone with the use of an ozone generator machine with an output of 3g/h. The ozone generator was operated following the manufacturer's specifications. Specimens were placed in a plastic jar with a plastic cover with one ozone gas injection port and distributed evenly throughout the jar, and one gas outlet for the release of the ozone gas. The ozone generator feeds dry compressed air as a feed gas. Ozonized air bypassed the specimens to supply a total airflow of ozone. The ozone gas/dry air mixture flowed into the jar for a certain 3 min. as determined by a pilot study. The ozone level inside the plastic jar was kept consistent during the time period by adjusting the outlet port.

Surface hardness and surface roughness tests

Acrylic specimens with the dimensions of (10x65x2.5) mm in width, length, and thickness were made for testing surface hardness and surface roughness (ISO 179, 2000), using a hardness tester (Time TH 210 Shore D) and portable tester of surface roughness respectively, (Figure 1).

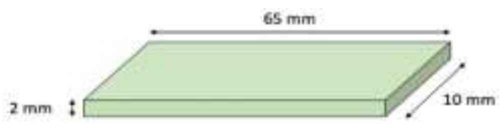

Figure 1: Dimensions of the Surface hardness and surface roughness test specimens.

Statistical analysis

Data were statistically analysed with SPSS version 21 (Social Science Statistical Package), which includes:

Descriptive statistics: Mean, Standard Deviation (SD), standard error (SE) Minimum, and Maximum, for the quantitative variable.

RESULTS

Surface hardness results are Beginning with 85.163± 0.615 to 86.434± 0.941. There was a significant increase in the gaseous ozone exposure group (III) compared to the control group (I) (p <0.05).

Table (1): Descriptive statistics of Shore D hardness among groups:

Groups	Mean	±SD	SE	Minimum	Maximum
Control	85.795	0.769	0.243	84.600	86.800
Microwave Radiation	85.163	0.615	0.194	83.930	85.830
Gaseous Ozone	86.443	0.941	0.298	85.000	88.000

Table (2): Statistical test of Shore D hardness among groups using One Way Analysis of Variance (ANOVA):

	Sum of Squares	df	Mean Square	F	P value
Between Groups	8.192	2	4.096	6.622	0.005 Sig.
Within Groups	16.701	27	0.619		
Total	24.893	29			

Sig.=significant at p≤0.05.

ANOVA test showed a significant difference among the studied groups (p ≤0.05).

Table (3): Multiple pairwise comparison of Shore D hardness among groups using Tukey's Honestly Significant Difference test (Tukey's HSD).

(I) Groups	(J) Groups	Mean difference	P value
Control	Microwave Radiation	0.632	0.190
	Gaseous Ozone	-0.648	0.175
Microwave Radiation	Gaseous Ozone	-1.280	0.003*

*=significant at p≤0.05.

Further investigation of statistically significant increase was obtained by using Tukey HSD. The result revealed a statistically non-significant difference between control group(I) and test groups (II) and (III) (p>0.05). while the result revealed a statistically significant difference among test groups (II) and (III).

For the surface roughness test, values ranged from 1.710± 0.380 to 2.204± 0.291. The findings of this investigation were statistically significant increase in surface roughness of gaseous ozone exposure group as compared to control group.

Table (4): Descriptive statistics of Surface roughness (μm) among groups:

Groups	Mean	±SD	SE	Minimum	Maximum
Control	1.710	0.380	0.120	1.274	2.277
Microwave Radiation	2.204	0.291	0.092	1.812	2.645
Gaseous Ozone	1.926	0.294	0.093	1.208	2.272

Table (5): Statistical test of surface roughness among groups using One Way Analysis of Variance (ANOVA):

	Sum of Squares	df	Mean Square	F	P value
Between Groups	1.228	2	0.614	5.833	0.008 Sig.
Within Groups	2.843	27	0.105		
Total	4.071	29			

Sig.=significant at p≤0.05.

ANOVA test showed a significant difference among the studied groups (p<0.05).

Table (6): Multiple pairwise comparisons of Surface roughness among groups using Tukey's Honestly Significant Difference test (Tukey's HSD).

(I) Groups	(J) Groups	Mean difference	P value
Control	Microwave Radiation	-0.494	0.006*
	Gaseous Ozone	-0.217	0.310^
Microwave Radiation	Gaseous Ozone	0.278	0.154^

*=significant at p≤0.05.

Tukey’s HSD test showed a statistically significant difference between the control Group (I) and test group (II) (p<0.05). while the result revealed a statistically non-significant difference between the control group (I) and test group (III) (p>0.05), furthermore there was a statistically non-significant difference among tested groups (II) and (III).

DISCUSSION

For their good properties, heat-cure acrylic resins are extensively used [12]. However, Plaque accumulation risk associated with these removable acrylic appliances because of surface porosities and food adherence configuration, which in turn increases the bacterial activity of cariogenic oral flora, which is one of the main issues that patients and dentists frequently encounter when using them [13]. Ozone is a form of oxygen, which has an effective role as an antibacterial and antioxidant agent. It is widely used in many areas of dentistry and has established itself as an efficient, reliable, and consistent disinfection [14]. After one minute of flowing ozonated water exposure (2 or 4 mg/L), little or no oral microorganisms and no viable Candida albicans were found, indicating that the use of ozonated water may be helpful in lowering the amount of C. Albicans on denture bases [15]. Because of the superior gaseous ozone effect over the ozonated water as proved by Oizumi, et al. in 1998 who found that gaseous ozone exposure directly was more effective [16], This research was designed to study the influence of gaseous ozone on surface hardness and surface roughness of heat cure acrylic resin.

Surface hardness refers to the resistance of a material to surface penetration or indentation [17]. This study used the Shore D hardness test since it is appropriate for materials made of acrylic resin [18]. There was a non-significant increase in hardness after gaseous ozone exposure as compared with the control group (I), this may be caused by the increase in the interchain forces that causes an increase in the surface hardness of PMMA acrylic resin [19]. These results contradict those of Durkan et al., who stated that using ozonated water may cause the oxygen to be converted into free oxygen radicals, which might lead to a softening of the acrylic resin chemically [20]. For the microwave radiation exposure, a non-significant increase in surface hardness compared with the control group was observed, this increase can be explained by, the water that the materials were submerged in was reached the boiling temperature. Therefore, it may be that the processes of additional polymerization and residual monomer release may have been enhanced by heating the acrylic resins during the disinfection procedures. As a result, the hardness of the specimens increased [21]. These findings are in line with other studies that found microwave disinfection methods had no detrimental effects on the hardness of denture base acrylic resin. They also found that repeated microwave disinfection or treatment with worm water did not cause significant changes in hardness for the heat-polymerizing acrylic resins examined [22].

Acrylic resin's surface roughness can vary depending on the material's properties, the polishing method, and the operator's skill [23]. Obtaining a smooth surface without scratches is an important objective for all resin materials because the increase in surface roughness may lead to deteriorating effects on denture aesthetic, while the decrease in surface roughness aids in restricting bacterial build-up and plaque accumulation [24]. There was a slight surface roughness increases after gaseous ozone exposure as compared with the control group (I), This may be explained by the potential retention of surface oxide-related substances during ozone application, which results in an increase in surface roughness [25]. There was a significant increase in surface roughness after microwave radiation exposure as compared with the control group (I), this may be related to the fact that the Specimens exposed to hot or boiling water showed a breakdown of the surface layer probably as a result of micro crazing of the surface, with the loss of integrity [26]. This increase in surface roughness possibly related to the fact that the surface layer of acrylic resins has a higher residual monomer content [21].

CONCLUSION

In fact, in vitro tests cannot predict exactly the clinical situation and more clinical studies is necessary to reach a definitive conclusion. Also, we must bear in mind the low sample size, So, With the study's limitations, it can be assumed that using gaseous Ozone exposure for acrylic resin as a disinfectant has no harmful effects on the surface hardness of heat-cured acrylic resin.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication and/or funding of this manuscript.

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