ORIGINAL ARTICLE

The Effects of Hydrogen Peroxide Solution on *Various Properties of* CAD/CAM based Polymethylmethacrylate (PMMA)

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ABSTRACT

Background: The daily and repeated immersion of dentures in disinfectant solutions can cause changes in the properties of PMMA, but there is lack of studies evaluating the effects of hydrogen peroxide disinfectant solution on CAD/CAM based Polymethylmethacrylate (PMMA).
Aim: To investigate the effect of hydrogen peroxide solution immersion on various properties (transverse strength, impact strength and surface hardness) of CAD/CAM based polymethylmethacrylate (PMMA).
Methods: 90 samples were prepared in this study. Samples were divided into 3 groups according to the type of the test used (transverse strength, impact strength, hardness), For each test 30 samples were further subdivided into ten samples for each of the three groups according to the type of treatment, 1st group control, 2nd group immersed in 3% hydrogen peroxide solution for 10 minutes, 3rd group immersed in 3% hydrogen peroxide solution for 30 minutes. Specimens in each group were subjected to the three-point bending test for transverse strength test, impact strength test and Surface hardness using shore D hardness tester. Scanning electron microscope (SEM). Statistical analysis was performed using two-way ANOVA and the data was considered statistically significant at a level of< 0.05.
Results: Statistical analysis of transverse strength test using two-way ANOVA showed non-significant increases in the mean value of the transverse strength for both immersion times, while a non-significant decrease of impact strength was found for both immersion times. Statistical analysis of Surface hardness test showed a non-significant decrease in the Mean value of the Surface hardness for 30 minutes immersion time and a non-significant increase for the 10 minutes immersion time.
Conclusions: CAD/CAM based polymethylmethacrylate (PMMA) Immersion in 3% hydrogen peroxide solution showed no significant effect and changes in the mechanical properties of the material specifically transverse strength, impact strength and surface hardness.
Keywords: CAD/CAM, disinfection, impact strength, transverse strength.

INTRODUCTION

Since 1936, acrylic resins or polymethylmethacrylate (PMMA) have been considered the most popular material to fabricate complete dentures[1,2]..Nonetheless, acrylic dentures are susceptible to fractures either intraorally or extraorally due to the brittleness of PMMA on impact[3,4].

After more than 100 years of conventional fabrication of complete dentures[5,6], computer-aided design/computer-aided manufacturing (CAD/CAM) technology has been recently applied in dentistry to the fabrication of complete dentures, record bases, immediate dentures, and implant-supported over dentures[7,8]. Structural properties of CAD/CAM PMMA-based polymers may overcome the conventional resins' well- reported shortcomings such as low mechanical stability due to porosity, voids, and polymerization shrinkage that occur during mixing, packing, and setting[9-11]. CAD/CAM PMMA-based polymers may decrease residual monomer release, improve color stability and optical properties, and simplify the production of prostheses with easy machining[12,13].

Denture bases and/or reline materials present surface irregularities and micro porosities that facilitate fungal/bacterial adherence and colonization through the formation of biofilms on the prosthesis surface. In this mode of growth, bacterial and Candida spp. proliferate as a community of adherent cells covered in an extracellular matrix[14]. This type of biofilm is resistant to several drug classes and is capable of withstanding high antifungal concentrations[15,16]. The clinical relevance of the presence of a biofilm on the intaglio surface of prosthesis is that the prosthesis can provoke palatal mucosa injury, facilitating stomatitis. In addition, poor oral mucosa or denture hygiene allows the adhesion of debris to the surfaces, which also can be a potential source of contamination[17]. Hydrogen peroxide has been used in dentistry for many years to bleach teeth, and in recent years the regular application of hydrogen peroxide has become more widely used as part of dental hygiene, particularly in combination with sodium bicarbonate ('baking soda'). There is a good evidence for the safety of hydrogen peroxide when used at low concentrations on a daily basis over extended periods of time, in self-administered oral health care products such as dentifrices and mouth rinses, these low concentrations neither damage oral hard or soft tissues, nor do they pose a significant risk of adverse long-term effect[18], also Hydrogen peroxide is active against a wide range of microorganisms, including bacteria, yeasts, fungi, viruses and spores[19,20,21.]

So the purpose of this in vitro study was to study the effect of hydrogen peroxide solution immersion on the mechanical properties (transverse strength, impact strength and surface hardness) of CAD/CAM based polymethyl methacrylate (PMMA).

MATERIALS AND METHOD

Sample grouping: A total no. of 90 samples were prepared in this study, Samples were divided into 3 subdivisions according to the type of the test used (transverse strength, impact strength, hardness)
For each test 30 samples were further subdivided into three groups according to the type of treatment:
1st group is the control. (10 samples)
2nd group is to be immersed in 3% hydrogen peroxide solution for 10 minutes. (10 samples)
3rd group is to be immersed in 3% hydrogen peroxide solution for 30 minutes. (10 samples)
General test specimen's preparation: AutoCAD design software was used to create the geometrical shapes with the required dimensions for the samples to be used in this study, after which they were exported in STL "stereolithography" file format to be processed later on in the dental design software "EXOCAD". After milling the samples, they were sliced into the final specimens using a lathe cutting machine.

To have a uniform smooth surface and for standardization, the discs were smoothed by silicon carbide paper of 500 grit using a rotation motion and polishing machine at 200 rpm for one minute. The discs cleaned with ethanol alcohol using ultrasonic cleaner to eliminate any contamination and debris from the polished samples[22]. To minimize the outcome variability, all preparations, polishing procedures, and evaluations were conducted by the same investigator. Prior to mechanical testing, the specimens were stored in water at a temperature of 37 (±1 _C) for 48 (±2) h. For transverse strength test the specimens were made with the following dimensions (65x10x2.5) mm length, width, and thickness respectively. (ISO 20795-1:2013)[23,24,25].

For impact strength test the specimens were made with the following dimensions (80x10x4) mm length, width, and thickness respectively according to (ISO 180:2019), ASTM D256 - 10(2018)[25-29]. For surface hardness test the specimens were made with the following dimensions (65x10x2.5) mm length, width, and thickness respectively according to ADA specification No.12 (ISO 1567, 1999).

Testing procedure

Transverse strength test: The transverse strength was measured by using three-point bending test in a universal testing machine. Prior to testing, a digital Vernier was used to confirm the dimensions of each specimen. The PMMA specimens were placed on two parallel supporting wedges with 50 mm distance apart and the load was applied in the center of the specimen at a crosshead speed of 1 mm / min. by way of rod that located halfway between the supporting wedges to make a bending until fracture occurred. The following formula was used to calculate the transverse strength[30]:

$T = 3FL/2bd^2$

T: is the transverse strength (MPa),
F: is the load or force at which fracture occurred (N),
L: is the span of specimen between the supports (50 mm),
b: is the width of the specimens
d: is the thickness of the specimen (3 mm).

Impact strength test: The impact strength test was conducted with an impact testing machine and Charpy method, prior to impact strength testing, a digital Vernier was used to measure the dimensions of each specimen. Each specimen was supported at end and then stuck by swinging pendulum of 2 joules. The reading of impact energy appeared on a scale in joule, as the Charpy impact strength was measured in kilo-joules/square millimeter so the following equation was used[30]:

$$Impact\ strength = \frac{\mathrm{E}}{\mathrm{bd}} \times 10^3$$

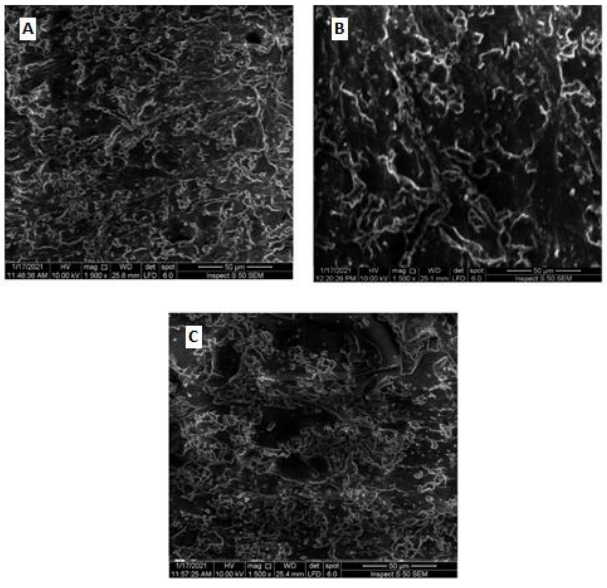
E: The impact energy in Joules.
b: The width of the specimen in millimeters.
d: The depth of the specimen in millimeters.

Surface hardness test: Surface hardness test was performed using shore D hardness tester (Time TH210 Shore D hardness tester). Hardness value was determined by measuring the depth of penetration of shore D hardness indenter (0.8mm), the range of measures was between (0-100) unit and the readings showed directly on a digital scale. The surface of specimens was divided into three equal thirds and one reading was taken for each third, and then the meaning of these three readings was measured.

RESULT

Microscopic examination (SEM): Figure 1 showing scanning electron microscopic image of PMMA specimens including control, 10 minutes immersion and 30 minutes immersion specimens.

Figure 1: scanning electron microscopic image for: A: control PMMA specimen; B: PMMA specimen after 10minutes immersion in 3% hydrogen peroxide; C: PMMA specimen after 30minutes immersion in 3% hydrogen peroxide

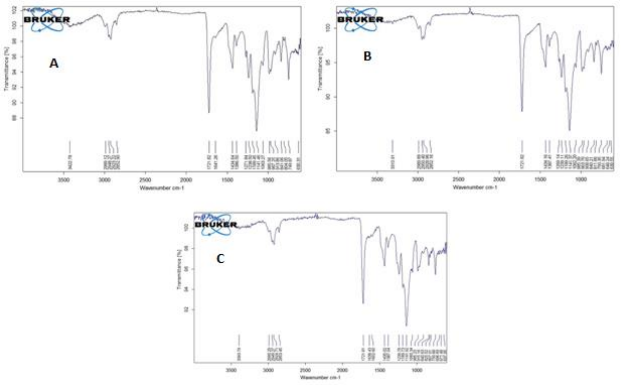


FTIR-Spectroscopy

PMMA: FTIR spectral result of PMMA (control) ,after 30 , 10 minutes immersion time in 3% hydrogen peroxide are shown in Figures(2) respectively. Chemically, there was no interaction between PMMA and hydrogen peroxide as there is no change in the spectral range of the material after the

immersion. FTIR spectral result shows no signs of degradation, losing of functional groups or separation of active peaks and this can be implied on the three groups (control and two immersion times).

Figure 2: A: Fourier transform infrared spectroscopy analysis result of PMMA after 30 minutes immersion in 3% hydrogen peroxide solution; B: Fourier transform infrared spectroscopy analysis result of PMMA after 10 minutes immersion in 3% hydrogen peroxide solution; C: Fourier transform infrared spectroscopy analysis result of PMMA control group



Transverse strength test : Table (1) showing the results of Mean, standard deviation, standard error, maximum, and minimum values in which the maximum value was for 30 minutes immersion time(C1)- 90.67 (N/mm2) ,while the lowest value was also for (C1)- 87.27 (N/mm2). Statistical analysis of transverse strength test using two-way ANOVA showed a non-significant increases in the Mean value of the transverse strength (N/mm2) for PMMA-Groups (B1),(C1)-(83.5070N/mm^2) (81.9160N/mm^2) respectively as shown in Table 2.

Impact strength test: Table 3 showing the results of Mean, standard deviation, standard error, maximum, and minimum values in which the maximum value was for the control group (A1)- 12.74 (KJ/mm2),while the lowest value was for 10 minutes immersion (B1)- 9.03 (KJ/mm2).

Statistical analysis of impact strength test using two-way ANOVA showed a non-significant decrease in the Mean value of the impact strength (KJ/mm2) for PMMA-Groups (B1),(C1) - (10.4130 KJ/mm2) (10.3500 KJ/mm2) respectively as shown in Table 4.

Surface hardness test: Table (5) showing the results of Mean, standard deviation, standard error, maximum, and minimum values in which the maximum value was for 30 minutes immersion time (C1)- 90.67 (KJ/mm2) ,while the lowest value was also for (C1)- 87.27 KJ/mm^2.

Statistical analysis of surface hardness test using two-way ANOVA showed a non-significant decrease in the Mean value of the Surface hardness (KJ/mm2) for PMMA-Group - (C1) – (88.8820 KJ/mm2) and a non-significant increase for the group (B1) – (KJ/mm2), (89.0650 KJ/mm2) respectively as shown in Table (6).

Table 1: Descriptive Statistics of PMMA

Dependent Variable	**Transverse**					
Technique	Material	Mean	Std. Deviation	Confidence interval 95%		N
				Lower bound	Upper bound	
Control (A1)	PMMA	81.8400	5.30311	87.5	90.1	10
10 minutes immersion (B1)	PMMA	83.5070	4.97869	87.56	90.37	10
30 minutes immersion (C1)	PMMA	81.9160	4.49323	87.27	90.67	10

Table 2: Tests of Between-Subjects Effects

Dependent Variable	**Transverse**				
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Technique	34.108	2	11.369	0.822	0.486
Error	995.855	72	13.831		

Table 3: Descriptive Statistics of PMMA

Dependent Variable	**Impact**					
Technique	Material	Mean	Std. Deviation	Confidence interval 95%		N
				Lower bound	Upper bound	
Control (A1)	PMMA	11.1090	1.25666	9.92	12.74	10
10 minutes immersion (B1)	PMMA	10.4130	0.93657	9.03	11.7	10
30 minutes immersion (C1)	PMMA	10.3500	0.88711	9.4	11.79	10

Table 3: Tests of Between-Subjects Effects

Dependent Variable	**Impact**				
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Technique	3.637	2	1.212	1.216	0.310
Error	71.765	72	0.997		

Table 5: Tests of Between-Subjects Effects

Dependent Variable	**Hardness**				
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Technique	2.517	2	0.839	0.883	0.454
Error	68.430	72	0.950		

DISCUSSION

Transverse strength test: The transverse (flexural) strength test is mainly helpful in comparing denture base materials in which a pressure of this type is applied to the denture during mastication. The transverse (flexural) strength is a mixture of compressive, tensile, and shears strengths, all of which directly reflect the stiffness and resistance of a material to fracture [(31).]. CAD/CAM PMMA-based polymers have more homogeneous structure, less water absorption, and solubility. Additionally, CAD/CAM PMMA-based polymers are stored in air until they are used, which ensures the post-polymerization process occurs accompanied with relaxation phenomena[32].

According to the results of the present study, Statistical analysis using two-way ANOVA showed a non-significant increases in the mean value of the transvers strength (N/mm2) and this might be due to the improved material properties. The non-significant effects of hydrogen peroxide disinfection can be explained by the homogeneous and highly cross-linked structure, and a polymerization process performed under optimized high pressure and temperature conditions[33]. The lack of porosity and voids may also be one of the reasons for the higher transvers strength of CAD/CAM PMMA-based polymers. As reported previously,**(34)** CAD/CAM PMMA-based polymers have a reduced risk of porosities and voids, which could be attributed to less water absorption and higher transverse strength.

Impact Strength test: Impact strength is the measure of energy absorbed by the material when it suffers sudden fracture. Ideally, denture base resin must offer sufficient impact strength to overcome the high extra oral impact forces which may occur as a result of dropping the prosthesis. This high impact strength must not interfere with other properties of the material[35]. Statistical analysis using two-way ANOVA showed a non-significant results in the Mean value of the impact strength after immersion in hydrogen peroxide which may be attributed to the unique processing method of the CAD/CAM PMMA pucks in which high temperatures and pressure values are used for CAD/CAM PMMA polymerization and also for the limited dispersion of hydrogen peroxide throughout the polymer matrix[6,36].

Surface hardness test: Surface hardness is defined as "the ability of a material's surface to resist permanent penetration or indentation"[37] In addition to being sensitive to monomer levels, it has been reported that there is a correlation between surface hardness and a material's mechanical properties[4]. Immersion in solutions may result in the material dissolving, caused by polymer degradation[38]. Polymer exposure to a solution results in hydrolytic degradation arising from the chemical interaction between the solution and the organic matrix in the free spaces between the chains in the polymer system[39]. Moreover, the active agents could result in accelerated chemical degradation. However, as observed in a previous study, agents with acidic and alkaline action did not result in an alteration superior to that of the hydrolytic solution. The non-significant results found in our study can be explained, in the case of hydrogen peroxide, by the limited diffusion of the hydroxyl radicals[40,41,42]

CONCLUSIONS

Within the limitations of this study it could be concluded that CAD/CAM based poly methyl methacrylate (PMMA) Immersion in 3% hydrogen peroxide solution revealed no significant effect and alterations in the mechanical properties of the material specifically transverse strength, impact strength and surface hardness.

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