وزارة التعليم العالي والبحث العلمي
جامعة ميسان
كلية التربية الاساسية

Ministry of Higher Education and Scientific Research
University of Misan
College of Basic Education

Misan Journal for Academic Studies

Humanities, social and applied sciences

مجلة ميسان للدراسات الاكاديمية

العلوم الانسانية والاجتماعية والتطبيقية

ISSN (Print) 1994-697X
(Online)- 2706-722X

المجلد23 العدد 51 أيلول 2024

Sep 2024 Issue 51 Vol23

مجلة ميسان للدراسات الاكاديمية

العلوم الإنسانية والاجتماعية والتطبيقية

كلية التربية الأساسية/ جامعة ميسان/العراق

Misan Journal for Academic Studies

Humanities, social and applied sciences

College of Basic Education/University of Misan/Iraq

ISSN (Print) 1994-697X (Online) 2706-722X

المجلد (23) العدد (51) أيلول (2024)

SEP 2024 ISSUE51 VOL 23

www.misan-jas.com

journal.m.academy@uomisan.edu.iq

رقم الايداع في دار الكتب والوثائق بغداد 1326 في 2009

الصفحة	فهرس البحوث	ت
16 - 1	**Using of the Two Tools Analytic Hierarchy Process (AHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) in Multi-Criteria Decision Making** Ali Dawood Salman Al-khanaqini Omar Mohammed Nasser alashary	1
26 - 17	**Investigation of piranha solution on Color Stability of heat cure acrylic** Noor Azher Al-Rubaie Aseel Mohameed Al-Khafaji	2
33 - 27	**Beamforming and Resource Allocation for Heterogeneous Bands in 6G** Mustafa N. Mnati	3
51 - 34	**The Sounds of Colours: A Pragmatic Study of Toni Morrison's The Bluest Eye** Rafah Abdulkareem Adham Hassan Muayad Hamid	4
60 - 52	**Diagnostic Accuracy of GCF IL33 and sST2 For Periodontitis Stage I, II, and III** Samar A. Abood Ayser N. Mohammed	5
76 - 61	**The Globalization of Human Rights: A Critical Assessment** Omowonuola OKUNNU Bimbo OGUNBANJO	6
87 - 77	**Impact of erythritol air polishing in supportive periodontal care: literature review** Muhsin Kadhim Abbas Hayder Raad Abdulbaqi	7
102 - 88	**Distributed Random Number Generation Fair and Reliable for Blockchain Applications** Mays Moneer Abd Ali Bashar M.Nema	8
114 - 103	**Adhesion of 3d printed acrylic resin with silicone soft liner after sandblast surface treatment (A Review of Literature)** Mohammed Taqi S. Wadi Bayan S. Khalaf	9
125 - 115	**Effect of Immersion Time of a Hydrogen Peroxide and Vinegar Mixture Solution on the roughness of Heat-cured and CAD/CAM Polymethyl Methacrylate Resin** Ahmed I.Shanef Firas Abdulameer Farhan	10
135 - 126	**Evaluation the Salivary levels of Interleukin-23 in Individuals with Thyroid Disorders** Riam Hassoun Harbi Maha Adel Mahmood	11
150 - 136	**The Interplay Between Chronic Kidney Disease and Periodontal Health: A Comprehensive** Ahmed M Mahdi Maha Sh Mahmood	12
157 - 151	**Ethics In Orthodontic Clinical Practice: (A review article)** Zainab Mousa Kadhom Alaa Faleh Albo Hassan Shaymaa Shaker Taha	13
172 - 158	**Preparing of Controlled Release Systems for Atenolol and Studying it is in Vitro Dissolution and Swelling** Mohammed R . Abdul - Azeez	14
179 - 173	**Evaluation the salivary *anti-Porphyromonas gingivalis* (IgA and IgG) response in relation to sera levels of Ferritin and Vitamin D in Patients with Beta-Thalassemia Major** Shahad fayiz abd Maha Adel Mahmood	15
188 - 180	**The role of different adjunctive plaque control modalities in orthodontic patients with gingivitis** Ola Issam majed Raghad Fadhil abbas	16

205 - 189	**Assessed performance of E-learning methods and benefit from (AI) for Undergraduate Engineering stage** Ali Dhahir Alramadhan	17
224 - 206	**The use of counterpoint in Kurdish orchestral compositions: (Dilshad Muhammad Saeed)** ary kadir Mohammed Seerwan Mohammad Mustafa	18
248 - 225	**Demographic Transitions and Spatial Reallocation of Population Variables in the Administrative Territories of Al-Majar Al-Kabeer District Over the Period 1997-2022** Ahmed Sihoud Hashem	19
263 - 249	**The economic and social reasons leading to the phenomenon of child labor in Al-Fuhud district in the year 2023** Osama Hameed Majeed	20
277 - 264	**Exposure to Iraqi satellite channels and its role in shaping public attitudes toward political organizations** Khuzaymah Nizar Khudair	21
294 - 278	**The Situational Implicture of Al-Sararqus in the Structural and Stylistic Correlation** Karima Abed Jumaa	22
314 - 295	**Isolate and Identification of Rhizoctonia solani Kühn causing Eggplant rot and accompanying bacteria with toxicity studying of fungicides and their effect in vitro** Alaa Hassan Al-Farttoosy Fatima Chasib Bader	23
331 - 315	**A Geopolitical Approach to the City ; with Emphasis on the Central Elements of Power and Competition** Hasan Kamran Dastjerdi Narjessadat Hosseini Abbas Ghali Al-Hadithi	24
347 - 332	**Patterns of Multiple Intelligences among High School Students in Misan Governorate According to The (TEEN-MIDAS) Scale and Their Relationship to Achievement** Haneen Mahdi Siker Ahmed Abdul-Muhsin	25
364 - 348	**The Impact of Transitional Regulations on the Application of National Reconciliation and National Amnesty Mechanism (A Comparative Study)** Hadi Hassan Kashash AlRikabiu Sayyid Ali Mirmad Najafabad	26
381 - 365	**Technical Diversity in Contemporary Kurdish Art** Sirwan Rafat Ahmed	27
389 - 382	**The interpretive approach at Al-Shahrastani** Mohammed Reda Salman Mohammed Ali Tajery Reda Moadeb	28
409 - 390	**The Degree of Consistency Between Mathematics Teachers' Beliefs Towards Constructivist Learning and Their Practice of its Skills** Haider Abdulzahra Alwan	29
420 - 410	**Hadiths posted about Imam Ali (peace be upon him) on social media platforms and their impact on society’s behavior** Lectuer.Mohammed Jabbar Jassim Ali	30
442 - 421	**The stylistic diversity that transformed the form and concept of contemporary visual arts.** Rajaa Kareem Jiboori Alobaidi	31

ISSN (Print) 1994-697X
ISSN (Online) 2706-722X

DOI:
https://doi.org/10.54633/2333-023-051-010

Effect of Immersion Time of a Hydrogen Peroxide and Vinegar Mixture Solution on the roughness of Heat-cured and CAD/CAM Polymethyl Methacrylate Resin

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ABSTRACT:

background: Several studies have confirmed the antimicrobial effect of a mixture solution composed of hydrogen peroxide 3% and vinegar 4% (HPV) as a disinfectant solution used for Polymethylmethacrylate (PMMA) denture base. Immersing dentures in this solution may result in alterations to the physical characteristics of PMMA. This in vitro study was conducted to examine the effect of different immersion times of HPV on surface roughness of heat cure and computer-aided design/computer-aided manufacturing (CAD/CAM) PMMA. **Material and methods**: 60 PMMA samples were prepared and divided equally according to two different types of PMMA materials: a) heat cure (H) and b) computer-aided design/computer-aided manufacturing (CAD/CAM) (A) PMMA. Each type was subdivided into three groups (10 samples for each) according to immersion time in the HPV mixture prepared with a ratio of (1:1); the control group was not immersed (H0 and A0), the second group was immersed for 90 days (H1 and A1) and the last group for 180 days (H2 and A2). Each group was examined before and after two immersion times with surface roughness measured by a portable roughness tester. The collected data were analyzed using Shapiro-Wilk for normality test and statistically analyzed with Two-way ANOVA. The data were considered statistically significant when $P \leq 0.05$. **Results**: statical analysis shows the highest surface roughness mean value was observed for the heat cure PMMA group (0.141). Statistical analysis showed no significant changes in the two immersion times (90, and 180 days) for both materials. **Conclusions:** The study concluded that HPV could be used as an alternative disinfectant solution for heat and CAD/CAM PMMA without promoting deleterious effects on surface roughness

Keywords: Disinfectant; CAD/CAM; PMMA; hydrogen peroxide and vinegar mixture.

INTRODUCTION:

Dental poly methyl methacrylate (PMMA) resin is a type of thermoplastic material that has been used for denture bases, tooth restorations, artificial teeth, and various other purposes in dentistry, due to its simplicity of manufacture, favorable properties, and affordable price. PMMA is widely recognized as the most often used material for denture bases.; however, the residual monomer, porosity, and polymerization shrinkage are a drawback responsible for the low mechanical stability of PMMA (Al-Dwairi ZN et al., 2020). The progress of knowledge and science has led to significant developments in Computer-aided design/computer-aided manufacturing (CAD/CAM) technology. This technology has been utilized in dentistry to create various treatments, including crowns, bridges, complete dentures, record bases, immediate dentures, and implant-supported overdentures. These advancements have revolutionized the traditional process of fabricating complete dentures, which has been in practice for over a century (Al-Dwairi ZN et al., 2020, Güth J-F et al., 2016).

CAD/CAM PMMA-based polymers offer several advantages over traditionally polymerized resins. These advantages arise from their highly cross-linked structure, changeable durability, and unique monomer and chemical composition (Karaokutan I et al., 2016). The structural features of CAD/CAM PMMA effectively counteract the drawbacks of traditional heat cure resins, including their poor mechanical stability due to porosity, voids, and the shrinkage that occurs during mixing, packing, and setting, as well as polymerization (Karaokutan I et al., 2015, Saini R et al., 2016). Additionally, Acrylic resins have a tendency to progressively absorb water or solvents over extended periods. This is mostly due to the inherent characteristics of the resin molecules and the resin's polarity properties (Al-Sammraaie MF et al., 2024), Acrylic-based resins undergo chemical breakdown and release residual monomers when they absorb large amounts of water at high equilibrium levels. The heightened water absorption by denture base resins leads to the development of internal stresses and the production of cracks over a period of time, subsequently affecting the mechanical characteristics, particularly the color stability, of dentures (Noori ZS et al., 2023).

Studies have demonstrated that the occurrence of denture stomatitis among those who wear dentures typically ranges at an average of 28%. Microorganisms can lead to the development of diseases in the mucosa that support the prosthesis, such as candidiasis (mostly caused by Candida albicans) (PEREIRA CJ et al., 2019).

The porous features of denture bases provide challenges in their mechanical cleaning, as it proves ineffectual in managing infections in dentures. Consequently, the practice of submerging prosthetic prostheses in disinfectant solutions has been implemented as a method to enhance the cleaning process. Nevertheless, most of these solutions possess drawbacks, including toxicity, corrosive impact on metals, irritating effect on the skin, and tissue discoloration. Hence, it is imperative to seek alternate solutions that provide disinfection capabilities without compromising the quality of the material (Al Qaysi HT et al., 2023).

Denture cleaners must eliminate biofilm without changing the denture base material's physical and mechanical characteristics. However, according to various studies, using denture cleaners frequently can have detrimental effects on the physical and mechanical characteristics of the dentures, including color, surface roughness, surface hardness, transverse strength, and other characteristics (MOHAMMED MA et al., 2019). One of the materials used in dentistry for a long time as disinfectants is hydrogen peroxide and more recently as part of oral hygiene. It is safe to use at low doses and is effective against a wide variety of microorganisms.

vinegar and hydrogen peroxide (HP) have been evaluated separately as denture disinfection. In the food business, combining vinegar and hydrogen peroxide is more successful than using vinegar (1% acetic acid) or 3% hydrogen peroxide alone to decrease bacterial levels (Soto AF et al., 2019). The aim of this in vitro study was to evaluate the effect of immersion time on heat cure and CAD/CAM PMMA in a solution consisting of low-temperature hydrogen peroxide and vinegar mixture on selected mechanical and physical properties. The null hypothesis is that the HPV mixture does not affect the mechanical and physical properties of heat cure and CAD/CAM PMMA.

Materials and methods:

Sample preparation and grouping:

sixty PMMA samples were prepared and divided equally according to the type of PMMA materials: heat cure (H) and CAD/CAM (A) PMMA (N = 30 samples). Each type was further subdivided according to the time of immersion in a mixture of hydrogen peroxide 3% and vinegar 4% (HPV) into (A) the control group which was not immersed in the solution (H0 and A0), (B) the second group was immersed for 90 days (H1 and A1) and (C) the third group (H2 and A2) was immersed for 180 days. Each group of 10 samples examined the effect of HPV on surface roughness. The geometrical shape of the samples was designed by a three-dimensional software (3Shape) with the specified dimensions (65x10x2.5) mm for length, width, and thickness, respectively according to (ISO 20795-1:2013) for surface roughness. The sample design was converted into the stereolithography (STL) file for subsequent processing in the dental design software by EXOCAD (version, Valletta 2.2) Fig (1).

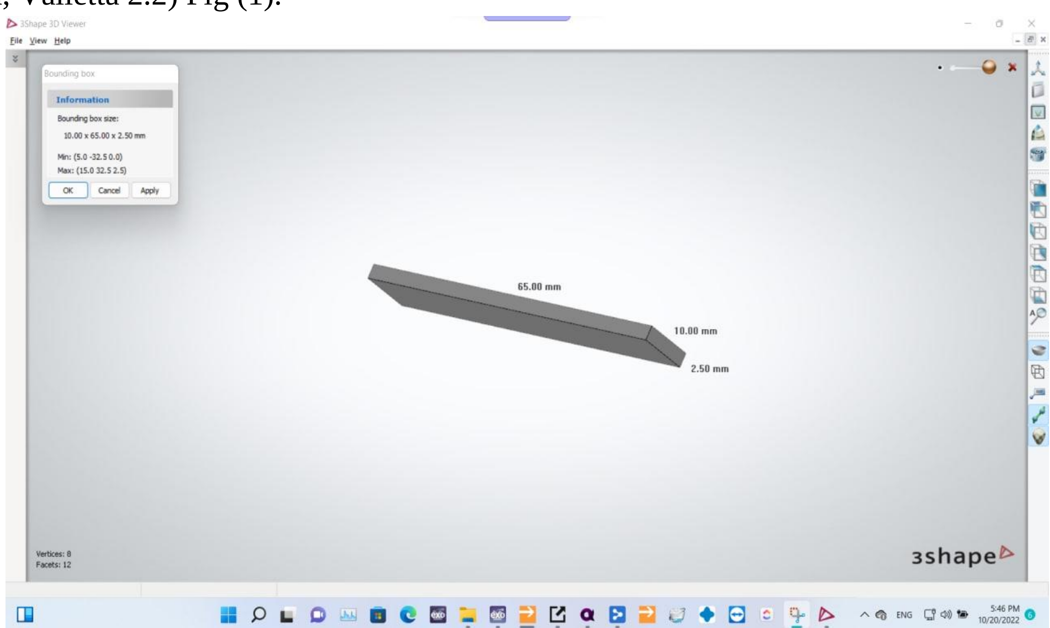

Figure (1): Three-dimensional design of PMMA sample

CAD/CAM PMMA samples were produced by exported STL files and processed by a milling machine (arum 5x -5000, Korea) using a PMMA block. Subsequently, the samples were separated, and the connectors were removed from the block manually using a handpiece Fig (2).

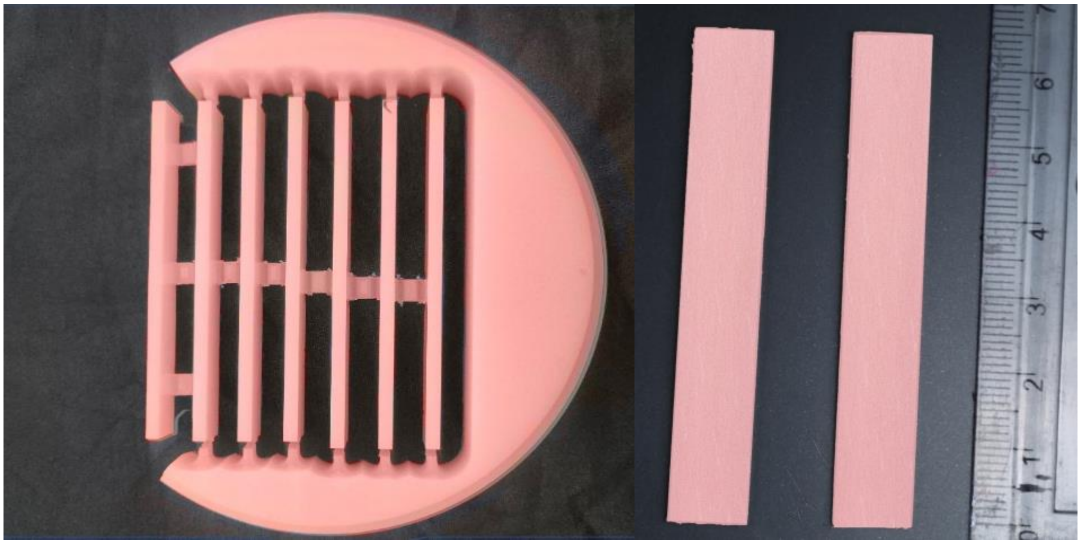

Figure (2): A- milled CAD/CAM PMMA block and samples for surface roughness tests

For heat cure PMMA samples, the same STL file and exported to the 3D printer (ASIGA, Australia) to fabricate the sample patterns. The patterns were placed in an ultrasonic bath for 10 minutes to eliminate any excess resin and cured in a specialized light curing unit to achieve complete polymerization according to the manufacturer's instructions. The patterns were painted with a uniform layer of separating medium and invested in a metal flask using die stone as investment material. To facilitate the removal of the models, (something missing here) was applied to both the stone and the models. After that the flask was opened and the models were removed, the heat cure acrylic was mixed according to the manufacturer's specifications. Compression molding technique was used for heat cure PMMA sample fabrication. The flasks were positioned within a water bath and subjected to rapid cycling for 45 minutes at a temperature of 100 °C according to the manufacturer's instructions. After that, the samples were extracted, cleansed, finalized, and refined (Fig. 3).

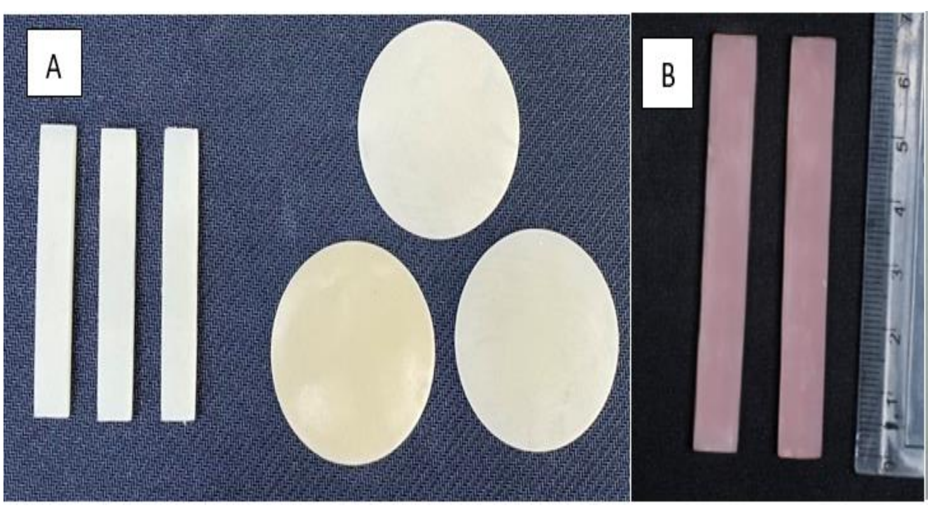

Figure 3: A: 3D printed pattern, B: surface roughness samples

to achieve a uniformly smooth surface and ensure standardization, the heat cure, and CAD/CAM PMMA samples underwent machine polishing. The polishing process involved a 2-minute duration and utilized a sequence of abrasive papers with grit sizes of 320, 400, 600, and 1200. The samples were polished for one minute by applying pumice slurry to a wheel brush. The samples were cleaned with ethanol alcohol in an ultrasonic cleaner for one minute.

Immersion procedure in HPV:

The disinfectant solution HPV was prepared by mixing 3% hydrogen peroxide and 4% vinegar with a ratio of 1:1. The hydrogen peroxide liquid of 250 ml was added to the 250 ml of vinegar solution in laboratory glassware and mixed using a magnetic stirrer. A cyclic immersion apparatus was constructed, incorporating an electronic timer and controller. The purpose of this device was to regulate the duration of immersion and compute the number of cycles. The immersion device submerges the samples first in HPV containers for 10 minutes. Subsequently, the arm withdraws the samples from the solution, allowing them to stand for 1 minute out of the glass beaker to drop the remaining HPV solution. Then the arm immersed the samples in the second glass beaker that contained artificial distal water for 10 minutes Fig (4). This cycle was repeated 90 times and 180 times, respectively.

Figure (4): Immersion cycle

Surface roughness:

To measure surface roughness, employ a portable surface roughness tester that utilizes a stylus to assess the microgeometry of a specimen's surface by maintaining touch with it. Three measurements were obtained from standardized locations, and the average of these three measurements was calculated.

Results:

The resulting data of all tests used in the current study was performed using the Shapiro-Wilk test and Kolmogorov-Smirnov test for normality. As listed in (Table 1), it was revealed that the significant level P-value was shown to be insignificant as a P-value > 0.05, which indicated that data originated from a normal distribution.

Table 1: Normality test (Shapiro-Wilk).

Test	Materials	P value
Surface roughness	Heat cure	P>0.05
	CAD/CAM	P>0.05

Descriptive statistics for the surface roughness test are seen in Table 2 in which the lowest mean value for heat cure acrylic-experimental groups (0.127) was in the H1 and H2 groups, and the highest mean value (0.129) was the H0 group, whereas the lowest mean value for CAD/CAM based PMMA-experimental groups (0.062) was found in A1 group and the highest mean value (0.063) was found in A0 and A2 group.

Table 2: Descriptive Statistics surface roughness test

Groups		Mean	SD
Heat cure	H0	0.129	0.015
	H1	0.127	0.014
	H2	0.127	0.010
CAD/CAM	A0	0.063	0.011
	A1	0.062	0.020
	A2	0.063	0.019

Table 3: Pairwise Comparisons between groups for surface roughness

Groups		Mean Difference (I-J)	Std. Error	P value
H0	H1	0.002	0.005	0.718
H1	H2	0.002	0.005	0.768
H2	H2	0.000	0.006	0.960
A0	A1	0.001	0.005	0.794
A1	A2	0.001	0.005	0.890
A2	A2	-0.001	0.006	0.920

Scanning electron microscopic (SEM) images of heat cure and CAD/CAM-based PMMA samples including control,90, and 180 days immersion samples there were no signs of surface dissolution or changes in the surface topography of the tested samples. Figure 5-6.

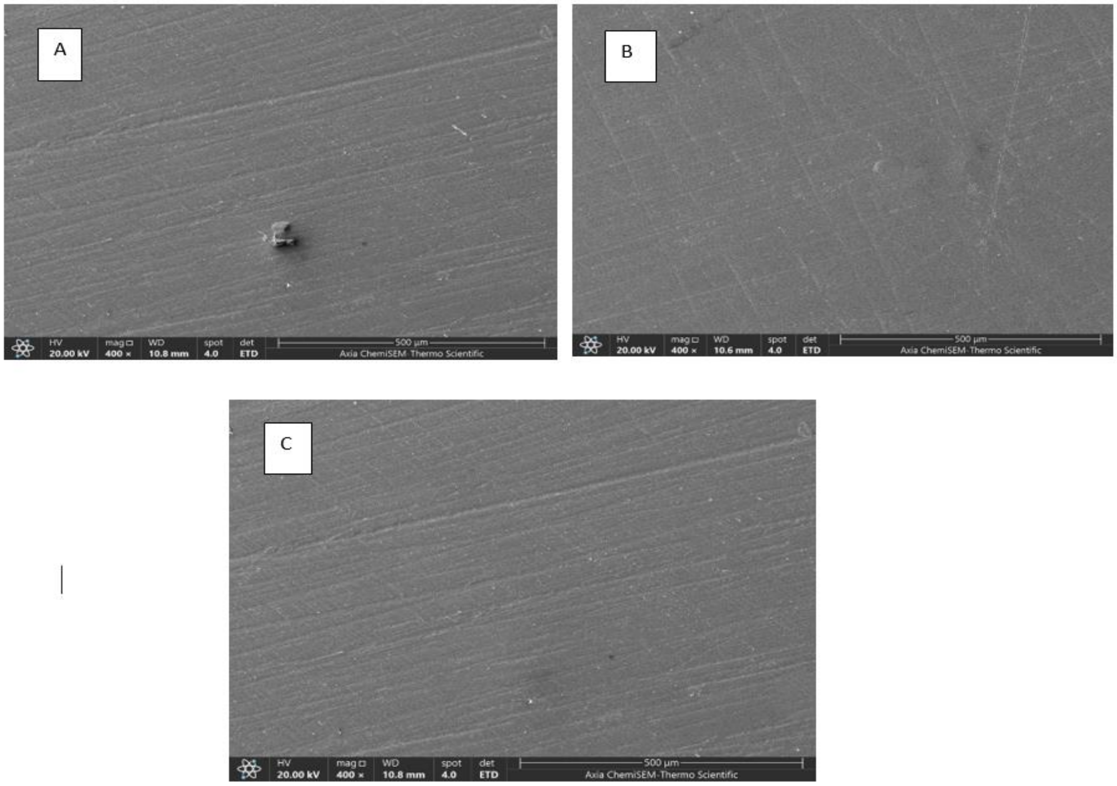

Figure 5: SEM images of heat cure PMMA samples: A: H0 group, B: H1 group, and C: H2 group.

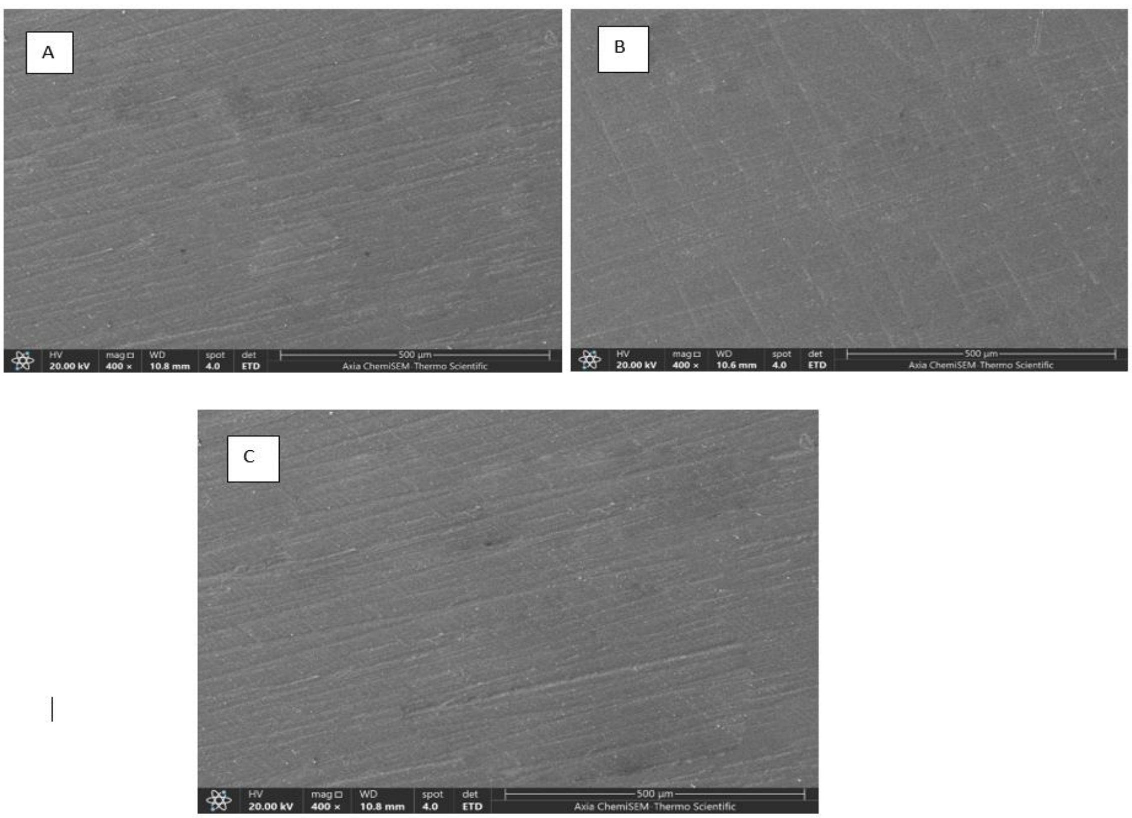

Figure 6: SEM images of CAD/CAM PMMA samples: A: H0 group, B: H1 group and C: H2 group.

Discussion:

A mixture of HPV has shown better antimicrobial effects than a single component which was approved throughout several studies (de Castro RD et al., 2015, Teixeira ÉF et al., 2023, Godara A et al., 2007). The effect of HPV on PMMA mechanical qualities varies based on the concentration, exposure time and material composition. Both chemicals are chemically reactive, which may influence the polymer structure and mechanical performance of PMMA (Katsigiannis AS et al., 2021). Hydrogen peroxide (HP) might cause an undesirable effect on the mechanical properties of PMMA, especially at high concentrations for a long immersion time. The polymer chain was degraded, resulting in decreased tensile strength, impact resistance, and flexural strength. However, with HP at low concentrations, its detrimental effect is removed and vanishes making it safe to use as a disinfectant (Soto AF et al., 2019). The vinegar which is an acidic solution containing acetic acid, may have some effect on PMMA. Acids can interact with PMMA and potentially cause changes in its mechanical properties. However, the effect of vinegar on PMMA is generally less significant compared to strong oxidizing agents like hydrogen peroxide (Teixeira ÉF et al., 2023) . Oral candidiasis is most commonly associated with denture wearers and is known as denture stomatitis. Although denture stomatitis has multiple causes, the primary risk factor is poor oral and denture hygiene care. Thus, routine denture cleaning regimes using commercial denture cleaners are recommended to prevent Candida albicans and related species invasion. Denture cleaning solutions were also employed to avoid plaque and extrinsic stain accumulation (Farina AP et al., 2012).

The current study found that CAD/CAM PMMA groups had lower surface hardness than the conventional heat-polymerized group, supporting the manufacturer's claim that CAD/CAM PMMA includes fewer residual monomers. According to a 2012 study by Farina et al (Farina AP et al., 2012), Furthermore, it has been found that there is a correlation between the surface hardness and mechanical properties of a material (Kimoto S et al., 2013).

Submerging the material in disinfectant solutions might lead to its dissolution, which is caused by the degradation of polymers (Kanno T et al., 2012). When a polymer is exposed to a solution, it suffers hydrolytic degradation due to the chemical interaction between the solution and the organic matrix in the interstitial spaces between the polymer chains (Muhammed SA et al., 2023). In the current study, the non-significant results observed can be explained by the limited diffusion of the free radicals (Kanno T et al., 2012, Gungor H et al., 2014).

The surface roughness of the denture base has been linked to its susceptibility to harboring stains, plaque, and bacteria (Mahross HZ T et al., 2015). Rough surfaces are more susceptible to discoloration and produce halitosis than smooth surfaces (Fatalla AA et al., 2020) , thus lowering the patient's comfort and acceptability. However, Microbial adherence and colonization usually happen on surfaces that do not shed, hence it is important for dental prostheses to have smooth surfaces. This reduces the build-up of plaque and microbes, ultimately increasing the lifespan of the prosthesis (Paulino et al., 2015).

So, the surface roughness of dental prostheses should be kept to a minimum (Mahross HZ T et al., 2015, Rao DC et al., 2015). In the present study, immersion in 3% hydrogen peroxide and 4% vinegar mixture solution did not result in a significant increase in surface roughness values for both heat cure and CAD/CAM-based PMMA, as observed in previous studies (Al Qaysi HT et al., 2023, Bidra AS et al., 2013). The CAD/CAM PMMA groups showed lower surface roughness values in comparison to the conventional heat polymerized group (P < 0.05), which supports Bidra et al's claim that CAD/CAM PMMA has better surface properties, less porosity, and eventually less microbial adherence (Bidra AS et al., 2013). Surface features of CAD/CAM PMMA may be related to the materials' unique manufacturing process; lower quantities of residual monomers as well as the polymerization method used in polymer manufacturing, which contribute to surface roughness reduction. The results of the present study support Murat et al's results of lower Ra values for the CAD/CAM materials using a contact-type profilometer and the results of Steinmassl et al (Steinmassl O et al., 2018, Murat S et al., 2016, Agarwal B et al., 2015). Solubility and water sorption are the major issues that harm durability. Water molecules infiltrate the interstices of the material's macromolecules, causing their separation. This behavior has an impact on the way dimensions behave and the stability of dentures. Consequently, it is important for the water sorption and solubility of these materials to be reduced (Nasser AA, et al., 2023, Mohammed MJ et al., 2023).

Conclusion:

Within the limits of this investigation, it was possible to conclude that the mechanical characteristics of surface roughness of the two materials were not significantly affected the immersion in a solution mixture of 3% hydrogen peroxide and 4% vinegar.

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