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The effect of using modified Flask on some properties of Heat-Cure Acrylic Resin

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Aim: The paper aimed to evaluate using a modified flask on surface hardness and roughness, flexural, and tensile strength for heat-polymerized acrylic resin.
Materials and methods: 80 specimens of heat-polymerized acrylic resin were prepared, and divided into two main groups. This division was followed type of flask that was used for processing the acrylic. 40 specimens of the first group (control) were prepared using a regular flasking technique, and the remaining 40 specimens were prepared using a modified flask which represented a second (testing) group.
Then each group subdivided into another four groups according to the test will be done (10 specimens for each test group) hardness, flexural strength, tensile strength, and surface roughness, a statistical analysis with a p-value ≤ 0.05 was carried out for values obtained.
Results: The amount of surface hardness (shore D) were 33.14 ± 2.04 and 29.57 ± 1.23; the flexural strengths (MPa) were 107.3 ± 9.54 and 89.92 ± 2.05; the tensile strengths (MPa) were 31.30 ± 8.46 and 15.50 ± 2.46; and surface roughness (µm) values were 1.15 ± 0.556 and 0.78 ± 0.29 for the experimental and control groups, respectively. There were noticeable effects on surface hardness, flexural and tensile strength with p-value < 0.05, and unnoticeable effects on surface roughness when compared between experimental and control groups.
Conclusion: According to the result of this study, the mechanical properties of heat-polymerized acrylic resin were improved using a modified flask with a new metal plate.

Keywords: Acrylic resin; Dental instruments; Flexural Strength; Hardness; Tensile Strength; Surface Properties.

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Introduction

For several years, poly methyl methacrylate (PMMA) has represented the material of choice for dental applications for their capability and effectiveness in constructing a wide range of applications in diverse fields.[1, 2] In 1843, Redtenbacher reported this material for the first time.[3] In 1930s, PMMA was firstly used as a denture base material; while in 1940s, PMMA gained increasing importance as a biomaterial for clinics and dental laboratories.[4] PMMA's popularity in the dental field is due to its numerous advantages such as ease in fabrication and processing, aesthetically appealing, low density, ability of colour matching and biocompatibility.[5-7] In contrast, PMMA has some disadvantages, including dimensional change, residual monomer content and insufficient mechanical properties especially flexural, impact strength and surface hardness which makes it highly prone to fracture and cause failure clinically.[3, 8, 9] As a result, the ever-changing requirements of the dental field require the denture base resin materials to exhibit good mechanical properties to be able to survive the various forces oral function and mastication.[5, 10] Many researches were carried out to advance the efficiency of PMMA.[3, 11, 12] Conventional methods of fabrication for Heat polymerized PMMA have remained unchanged relatively since 1936.[13] It may be influenced by many parameters like variations in temperature and time. Although a numerous process is used for polymerizing dental monomers and convered it to polymers; the polymerizing process is still uncomplete, and few monomers are remaining unreacted known as (residual monomers). The low-molecular-weight residual unreacted monomer acts as a plasticizer, which has an adverse affect on mechanical and physical properties of acrylic resin.[14-16] In recent years, procedures for curing heat cure dental resin have been adjusted to enhance thier mechanical properties. A study by.[11] used a dental flask modified with tongue-like metal plate attached with the upper member of flask for curing heat cure dental resin to distribute a high temperature generated inside the flask in order to decrease the porosity of dental resin. A study concluded that the quanitity of pores were decreased and the mechanical properites were enhanced. However, there are no researches that have studied the effect of using a modified flask on the physical and mechanical properties of acrylic resin. Therefore, the current research aimed to investigate the effect of a modified flask on surface hardness and roughness, flexural and tensile strength of processed heat-cure dental resin.

Materials and Methods

Specimens' grouping

80 specimens of heat-cure acrylic resin (Veracril, new Static S.A.,Colombia) were prepared and divided into two main groups according to the type of flask that was used for processing the acrylic. 40 specimen for control group was packing with a regular flask and the another 40 specimen for testing group was packed with a new modified flask. A newly modified flask with a projector tongue-like shape was locally manufactured and designed by the researcher and was constructed from pure copper (Fig.1, B). A projector was securely attched to upper member of the flask with screws. Then, every main group was subdivided into another four groups (10 specimens for each test group) for testing surface hardness, flexural strength, tensile strength, and surface roughness.

Specimens' preparation

Four different metal patterns were prepared by cutting stainless steel plate into desirable dimensions and shapes according to the required test by using turning machine. The metal patterns were then invested in a dental flask, using dental stone to create the acrylic resin's mould. The mould space obtained was used for test spacemenc's preparation. The powder and

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liquid of heat-cure acrylic resin was mixed and packed in the mould cavity according to the manufacturer's instructions. All specimens were pressed under 3000 PSI with a hydraulic presser. A conventional polymerization technique was used by insertion the flasks in a water-bath device at 100°C for 30 minutes according to manufacturers' instructions. After the acrylic resin was polymerized, all the execsses were eliminated with a bur of tungsten-carbide. Then, specimens were polished and stocked in distilled water at 4˚C until use.

Hardness test

Specimens of 20 disc-like shape were prepared for a hardness test with a diameter of 40 mm and thickness 3 mm. A Shore D durometer instrument (China) was used to test the hardness value of the specimens according to ASTM D2240 standards. The Shore device has a needle applied perpendicular to the sample with a 50 N. load for 15 seconds (dwell time). To obtain correct readings, the surface of the specimens must be smooth and clean with a thickness of not less than 3 mm. Each specimen was tested six times at different positions on each specimen at the same time, and the final hardness was an average of them.

Flexural strength

In order to assess the test of a flexural strength, specimens of 20 rectangular-like shape with a length of 50mm, width of 20mm and 4mm thickness were fabricated. Three-point flexural strength test was performed according to ASTM D790 standard. Before test, all specimens were stocked in a distilled water for 10 days at room temperature. This test is accomplished by a universal testing machine using a three-point bend fixture at a degree proportionate to the specimen’s depth. To fracture the specimens, it should be placed on supports with a distance between the support span of 40 mm and compressed with a crosshead at a speed of 5 mm/min. A diameter of loading and supporting plungers was 20 mm. The highest force exerted on the specimens was measured and flexural strength values were counted with the equation ($F=3WL/2bd^2$). Where F: is the flexural strength, W: is the load at fracture, L: is the distance between the support span (mm), b: is the width of specimens and d: is the specimen thickness (mm). Flexural strength value was calculated in MPa.

Tensile strength

tensile strength test, 20 dumbbell-shaped specimens were prepared following ISO 527 standards with the dimensions shown in (Fig. 1,C).

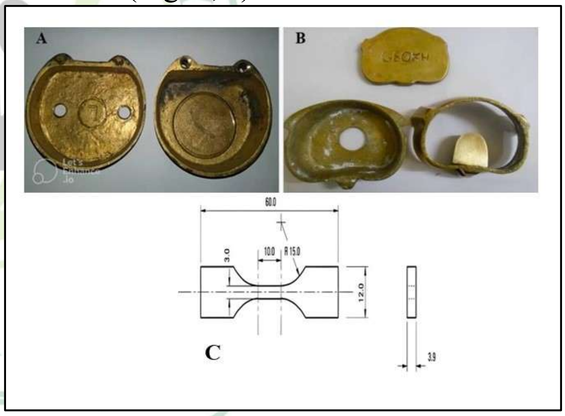

Figure 1: A. Ordinary flask of processing, B. Modified flask of processing, shape and dimensions of tensile strength specimen.

The tensile test was done according to ASTM (D638-03) standards at room temperature using universal testing machine, model (WDW-5E, China). The two ends of the specimen were connected to the jaws of the device. A tensile force, by computer control, was applied with the load equal to (5 kN) at strain rate of (5mm/min) until failure occurred in the specimen. Tensile strength calculation was automatically done by the program of the testing machine software.

Surface roughness

To measure the surface roughness value, rectangular specimens were fabricated with 50mm length, 20mm width and 4mm thickness. A profilometer

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(TR200, Time Inc., China) was approved to estimate the rate of surface roughness of specimens. Each specimen was fixed on platform and a probe of tester was slightly in contact on the specimen's surface; a probe was passed over whole specimen's surface, and the reading was recorded. For that specific specimen, the average measurement was used to get the rate of surface roughness.

Analyzing Statistic

A descriptive statistic including mean, standard deviation SD, and standard error SE with an inferential statistics including analysis of variance (one way ANOVA) were approved at 95% level of confidence (P≤0.05).

Results

The results obtained from the current study showed the following: the hardness, flexural strength and tensile strength have significantly been improved by processing heat-cure acrylic with modified flask,, while there was a non significantl increasing in roughness of acrylic resin's surface.

Hardness test

Processing of heat-cure acrylic resin with modified flask increased the ShoreD hardness mean values (33.14 ± 2.04) in comparison to control group (29.57 ± 1.23) as shown in (Table 1). Furthermore, an increase in surface hardness was statically highly significant as illustrated in (Fig.2).

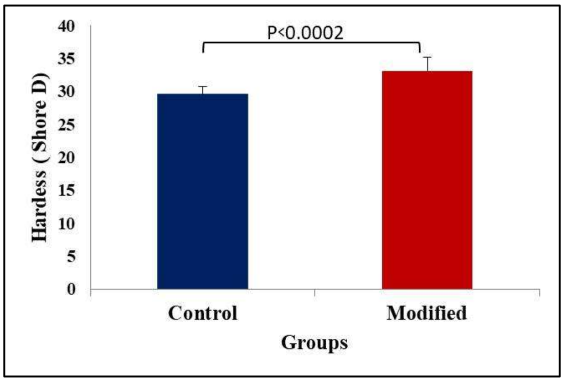

Figure 2: Bar chart of hardness mean values.

Flexural strength

(Table 1) shows the mean and SD of flexural strength test of testing groups. In general, processing heat cure acrylic resin with modified flask showed an increase in flexural strength mean values (107.3 ± 9.54 MPa) when compared to control group (89.92 ± 2.05 MPa) which is statically highly significant as shown in (Fig. 3).

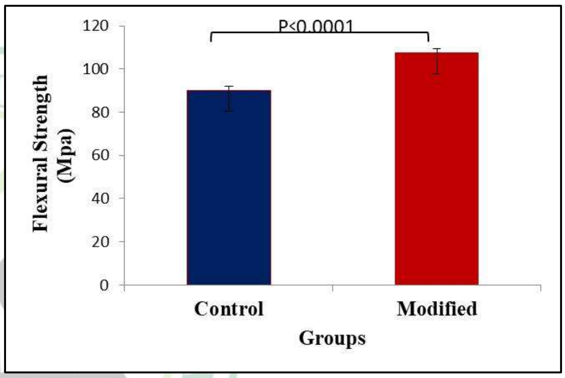

Figure 3: Bar chart of flexural strength mean values.

Tensile strength

Results for tensile strength test presented in (Table 1) and (Fig. 4). The tensile strength of experimental group revealed a considerably higher mean value (31.30 ± 8.46 MPa) compared to control group (15.50 ± 2.46 MPa) with a high statistical significant difference between the two groups.

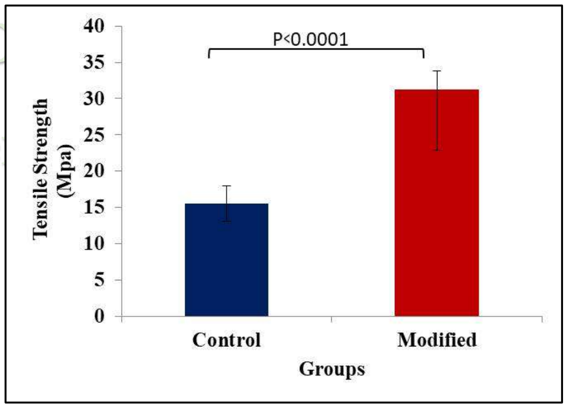

Figure 4: Bar chart of tensile strength mean values.

Surface roughness

Heat cure acrylic processed with modified flask showed an increase in surface roughness mean values (1.15 ±

0.556) (µm) compared to control group (0.78 ± 0.29) (µm). The mean value of surface roughness was increased with statistical non-significant difference between the testing groups (Table 1) and (Fig. 5).

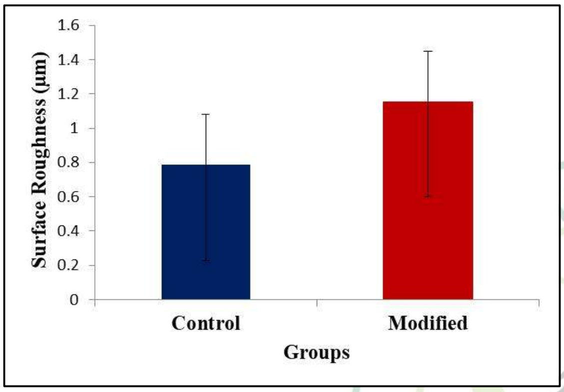

Figure 5: Bar chart of surface roughness mean values.

Table 1: A descriptive statistic for the hardness, flexural strength, tensile strength and surface roughness groups.

	Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Shore D hardness	Control	10	29.57	1.237	0.3913	28	31.3
	Experimental	10	33.14	2.041	0.6454	30.2	36.2
Flexural strength	Control	10	89.92	2.059	0.6512	85.98	92.1
	Experimental	10	107.3	9.546	3.019	98.9	121.4
Tensile strength	Control	10	15.50	2.461	0.7782	12.00	19.00
	Experimental	10	31.30	8.460	2.675	22.00	44.00
Surface roughness	Control	10	0.7859	0.2932	0.09272	0.34	1.232
	Experimental	10	1.155	0.556	0.1758	0.336	1.966

Discussion

The current research was carried out to evaluate the surface hardness, flexural strength, tensile strength and surface roughness of heat-cured acrylic resin after using a modified flask. According to the information and sources collected to achieve this research, there are no previous published studies concern with the effect of using a modified flask on the mechanical and surface properties of heat-cured polymer.

A residue excess monomer present in the dental appliances had an adverse effect of the mechanical and surface properties.[17] Recent studies demonstrated that there was clear relaionship between surface hardness, tensile strength, transverse bend strength and the amount of residue excess monomer content.[15]

A Residue excess monomer acted as a plastizer that led to decrease the force of interchain of polymer chains that was attributed why it was easy to deform the material under load. Therefore, it was considerd as an important factor to determine the properties of acrylic resin.[1, 15, 18]

Surface hardness was known as "permanent resistance of the material's surface to penetration or indentation".[19] Using modified flask led to improvement in surface hardness of hea- cured acrylic resin. The mean values of experimental group of PMMA demonstrated a significant increase in hardness (33.14) in comparison with the control group (29.57).

[11] studied the opportunity of decreasing the pores presented in heat- cure acrylic material by modifing a flask used for curing acrylic material. The authors reported that the temperature of the acrylic material might be decreased and inhabit the monomer from reaching to its boiling temperature during using a modified flask with metal plate leading to pores decrease of the processed acrylic resin. This study's findings were in agreement with the above-mentioned study as this increase in hardness might be due to reduced a content of residual monomer. Another study by [14] reported that a higher surface hardness for heat-cure acrylic resin might be obtained by polymerizing with autoclave technique comparing with those polymerized by water bath technique and that argued a significant reduce in residual monomer content. Results obtained for flexural strength indicated that the heat cured PMMA resin polymerized with modified

flask had a significantly higher flexural strength mean values (107.3 MPa) than control group (89.92 MPa). The flexural strength of dentures plays a vital role in understanding how well a resin will perform under the stress of mastication/chewing.[5] A study by[20] proved that reduced porosity caused by reduced content of residual monomer in dental acrylic is essential to obtain durable copolymer structure with high flexural strength. However, in the current research, the values of flexural strength were above the minimum amount of flexural strength that recommended for denture base acrylic resin (65 MPa) according to ISO 20795-1-2013.

Also, for tensile strength test, PMMA resin polymerized with modified flask showed significantly higher mean tensile strength value (31.30 MPa) than control group (15.50 MPa). As discussed earlier, the resulting heat formed from a process of polymerization had been absorbed by the metal plate in the modified flask, and that positively decreased temperature of acrylic resin and the evaporation of monomer which in turn reduced the porosity of acrylic resin.[11] However, in this study, the increased tensile strength might be attributed to the decrease in plasticizing effect caused by the decrease of residual monomer content. These findings agree with[21] who reported that the most likely cause of porosity is monomer evapotated due to high temperature (exothermic reaction + external heat).

Despite the lack of sufficient scientific evidence on the effect of modified flask on roughness of heat-cure acrylic resin for purpose of comparison, the results of the current research presented non-significant statistical increase in roughness mean values (1.155 µm) during comparing with control group (0.785 µm). A recent study by[12] using autoclave technique for polymerizing heat-cure acrylic resin might be reduced the materials' surface roughness and this is argued to heat degree and amount of pressure used for polymerizing process by autoclave, and the surface roughness improved due to increase conversion residual monomer to polymer.The current findings were in disagreement with the above-mentioned study. This can be attributed to the differences in polymerization methods, polishing techniques and/or another resin type.

Based on the results of this research, polymerization of heat cure acrylic resin using modified flask improved hardness, flexural strength and tensile strength of tested material and increased surface roughness. however, surface roughness can be managed by proper polishing techniques. Therefore, polymerization of heat-cure acrylic resin with modified flask is recommended and could be used as an alternative method to ordinary flask polymerization. In addition, future studies are recommended to include more brands of PMMA and expand the range of mechanical and surface properties to be evaluated.

Conclusion

The present study findings concluded that using modified flask with metal plate enhanced surface hardness, flexural and tensile strength; and non-significantly increased roughness of heat-cure acrylic resin which processed with conventional water bath method.

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Ethics approval

No need for ethics approval.

Competing interest

Authors declare no conflict of interest.

Data availability

Additional data will be made available on request

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