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Preparation of Metal Mold For Production Of Microwave Flask

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ABSTRACT

Aims: To design and prepare a metal mold used for production of Fiber Reinforced plastic flask (FRP) suitable for curing of acrylic resin by microwave irradiation, and investigate the effect of the following variables on the shear bond strength (SBS) of acrylic teeth to acrylic denture base material: A-curing techniques (water bath and microwave). B-surface treatment with monomer. C-cross – linking of the tooth resin by using the new microwave flask. **Materials and methods**: The FRP flask is not available in our country so as a special design of metal mold was prepared for this study. Inner dimensions were determined according to standard Ash metal flask. A microwave flask was fabricated from unsaturated polyester resin reinforced with glass fibers, nuts and screws was fabricated from Teflon material which are available in our country. One hundred sixty samples of five different brands of acrylic teeth were divided into four groups {untreated and treated (with monomer)groups each of these were cured by water bath or microwave techniques}. The bond strength between acrylic tooth and denture base resin was measured in shear mode by using unconfined compression machine, the SBS in MPa was calculated. Analysis of variance (ANOVA) and Duncan's multiple range test were used for statistical analysis. **Results**: There was a significant differences in bond strength of acrylic denture base to different tooth materials by using FRP flask in relation to Ash metal flask at ($P < 0.001$). **Conclusions**: SBS of acrylic teeth improved by monomer surface treatment for 180 seconds to microwave cured resin by new prepared flask (FRP) was significantly higher than that of water – bath cured resin, and cross – linked acrylic teeth showed lowest SBS compared to other type of acrylic teeth.

Key words: Microwave, Bond strength of teeth, FRP flask, Metal Ash flask

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INTRODUCTION

Nishii[1] was the first author who faced the problem of microwave radiation reflection by metallic flask, and in order to overcome this problem he suggested perforation of the metal flask.

Another trial to solve the problem of microwave reflection by metallic flask was by removing the investing plaster containing the dough from the flask and binding tightly with rubber tube and followed by normal microwave irradiation of 200–500 watts for 3 minutes. Satisfactory results were obtained by this method[2].

Researches and trials continued until Kimura and Teraoka [3] solved the problem by introducing the fiber re–enforced plastic flask (FRP) made from glass fiber re–enforced plastic with polycarbonate bolts and nuts. Such flask allows the transmission of microwaves into the mold without heating its walls, thus internal materials are heated only. Such flask succeeded and became widely used. Also, other researcher described the use of this type of flask [4]. Translucent materials was used such as a common resin, high resistance ceramic or unbreakable glass for making flask suitable for microwave curing better results was obtained [5].

Studies showed that the most disadvantages of microwave technique were related to the plastic flask (fiber re–inforced plastic flask). The flask is relatively expensive and has tendency to break down after processing several dentures. The polycarbonate bolts tend to break or the threads strip if tightened too firmly [6]. Also, difficulties that occurred with the polycarbonate bolts, copious amount of petroleum jelly being needed to promote their removal [7].

Mckinstry and Zini [8] described a method for making a dental stone flask pattern and a latex mold makes it possible to produce fiber glass flasks strong and large enough to accommodate obturators and other large intra–oral prostheses

In Iraq, several trials had been carried out in order to prepare the flask suitable for curing purposes by microwave oven and succeeded in the preparation of Iraqi Fiber Re–inforced Plastic (IFRP) flask without using metal mold [9].

The aims of this study are to design and prepare a metal mold used to produce a fiber reinforced plastic flask (FRP) suitable for curing of acrylic resin by microwave irradiation, and to investigate the effect of new (FRP) flask in relation to Ash metal flask on the shear bond strength of acrylic teeth to acrylic denture base material cured by water bath and microwave techniques.

MATERIALS AND METHOD

Materials used in this study for FRP flask are :

Metal plate of carbon steel (gauge16, 2.5mm.), arc welding (TIANJIN YANQIAO WELDING MATERIALS CO. LTD. CHINA), fiber glass liquid resin, which is an unsaturated polyester resin, grade upol-A-50, inter mediate petrochemicals industries Co. Ltd│p│, Amman , Jordan(Diameter 13.5micron, width 0.7mm.), 10% peroxide solution as catalyst, glass fiber, Cobalt naphthenate as an accelerator, Teflon material rod. Form of Glass fibers : Uni-directional roving fabric (Diameter=13.5µm., and Width=0.7mm.), and Total length of fiber (4500cm.)

A special design of metal mold was prepared to construct a microwavable flask.

The new metal mold consists of 2 divisions, first division for production of the upper half of the flask and its corresponding cover, while the second division for production of the lower half of flask and its corresponding cover (Figure 1). Each division consists of 3 elements: outer metal ring, inner metal ring and the metal base.

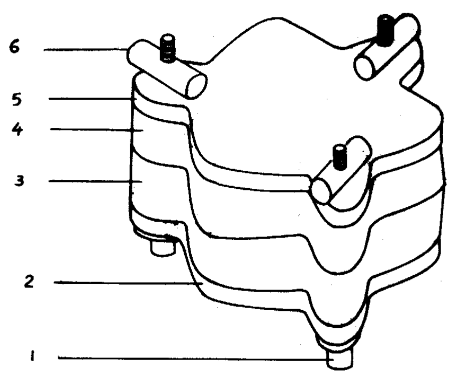

Figure (1): Schematic drawing of assembled FRP(MINARA) flask 1: Bolt. 2: Lower FRP cover. 3: Lower half of FRP flask. 4: Upper half of FRP flask. 5: Upper FRP cover. 6: Nut

Procedure:

1- Preparation of Paper Pattern and Metal Plates: The metal mold was made by using paper pattern to determine the inner dimensions of the flask. A thick paper was adapted carefully to the inner side of lower half of Ash metal flask to prepare the pattern, then the paper pattern of the inner side of the lower half of Ash flask was traced onto metal plate (carbon steel, gauge 16, 2.5 mm), and cut out the metal plate.

The same procedure was used for preparing metal plates for inner side of the upper half of Ash metal flask, and for the upper and lower covers.

2- Preparation of Outer and Inner Metal Rings and Metal Bases: To construct a new metal mold with the same dimensions, form and divergence of inner side of lower half of Ash flask, the prepared metal plate was softened by using heat (800–1000 ºC) and adapted carefully (using special handling instruments) to the inner side of the lower half of Ash metal flask. After cooling the plate was removed carefully from the flask and welded (Arc welding, TIANJIN YANQIAO WELDING MATERIALS CO. LTD. CHINA). The same procedure was used for designing and preparing the inner metal ring for inner side of the upper half of Ash metal flask.

The outer metal rings for upper and lower halves were designed and prepared specially for this study with space (8 ± 1 mm) between the outer and the inner rings (wall thickness of FRP flask) and incorporation of additional space at 3 areas of the outer ring which act as rooms for bolts. Also the outer ring was designed to give FRP flask a proper geometrical outline without sharp angles.

Metal plates designed for covers, also prepared and shaped to form the metal bases (with 10 mm thickness) which held the outer and inner metal rings, 3 metal projections (2 mm length) were incorporated at the corners of the base in order to accommodate for fixing the inner metal ring in its position to prevent its lateral shifting during pouring of fiber glass slurry (Figures 2).

Figure (2) The new metal mold of micro-wave flask (MINARA).

These metal bases have 2 functions: (1) hold the outer and inner metal rings in fixed position during processing the fiber glass slurry; and (2) act as a metal mold for production of FRP covers with 10 mm thickness.

A straight metal rod was fixed to the inner surface of the metal ring for easy separation of the metal mold after casting. Finally, it had been ensured that the first division was fully adapted on the second division so that the upper and lower halves of FRP flask have even and intimate contact.

Preparation of Fiber Re–inforced Plastic (FRP) Flask (MINARA flask): One thousand gram of fiber glass liquid resin (which is an unsaturated polyester resin) [grade upol -A- 50, inter nediate petrochemicals industries Co. Ltd |p|, Amman, Jordan.], (30) g of 10% peroxide solution as catalyst, (38) g of cobalt naphthenate as accelerator with (750) g of glass fibers were mixed well to create a thick slurry (the used ratio was according to the manufacturer's instructions).

After coating the metal mold with proper separating medium such as vaseline, a thick slurry of fiber glass mixture was poured in the metal mold by using vibrator device in order to eliminate air bubbles, and to ensure that the slurry mixture fills all parts of the metal mold completely.

The resin was allowed to harden at room temperature (23 $\pm$ 2 ºC), for eight hours. Then the metal bases were gently removed, inner metal rings, and outer metal rings were removed respectively. So by this manner, upper and lower halves of FRP flask were obtained with (8 ± 1 mm) uniform thickness.

The FRP covers (10 mm thickness according to Ash Flask) were prepared by using the metal bases as a mold. The same method described above was used. However, (700) g of fiber glass liquid resin, (21) g of 10% of peroxide solution, (26.6) g of cobalt naphthenate solution, with (525) g of glass fibers, were mixed well to create a thick slurry.

After the four parts of FRP (**MINARA)** flask (upper and lower halves with 2 covers) were assembled and slight trimming of the excess was done. Three perforations were made (in an area especially designed for this purpose) by drilling vertically through these four parts of the flask so that they can be clamped by 3 bolts and corresponding nuts, and washers (Figure 3).

Figure (3) Parts of FRP (MINARA) flask.

Three bolts (diameter 7.5mm, length 11 cm) and their corresponding nuts and washers for FRP flask were designed and manufactured from Teflon material [Trademark, Bayer, Germany]. Teflon material was used for bolts, nuts and washers materials in this study as it has the following properties: It has dielectric constant of about (2.4), and a dissipation factor of around (0.0004). Also, the dimensional stability of Teflon material is excellent, both with temperature, humidity and processing [10].

Preparation of samples for Shear Bond Strength Test: stone base with one hundred sixty of acrylic teeth for upper right central incisors from each of 5 different brands of acrylic teeth (Abdul−Nour, Supr-Cryl, Flori−Dent, Major−Dent and Super−Lux) were selected. Central incisors were divided into four groups, each subgroup contain 8 samples.

A rubber mold of casting ring was used to prepare (round form) stone bases (13 mm thickness, 65 mm diameter). About 4mm of the incisal portion was embedded in the stone mixture (immediately after pouring the stone and before setting) only ridge lap portion appears out of the stone mixture, and the long axis of each tooth being perpendicular to the stone base by the use of an analyzing rod. One tooth was placed at the center and seven teeth at the periphery with 10mm spaces from each other and 7 mm medial to the edge of the mold. A portable engine hand piece was fixed on surveyor arm, constant speed (40000 rpm) was used for cutting the ridge lap portion of each tooth by using carborandom disk. A silicon rubber mold was specially designed for this study to prepare a wax pattern of 5mm diameter and 2.5mm thickness that represent thickness of denture base (ADA specification No. 12, 1975) on the prepared flat tooth surface.

Flasking, Wax Elimination, Pacing and Curing of PMMA Resin was done by conventional water–bath curing technique (slow two–steps polymerization, 70 ºC for 30 minutes, then at 100 ºC for 30 minutes).

Microwave Curing Technique**:** To soften the wax, the FRP(MINARA) flask was microwaved for 1 minute at high setting (500 watts). For curing the FRP flask was placed in the microwave oven for 30 minutes at the low setting (80 watts), 15 minutes per side, followed by 1 ½ minutes at the high setting (500 watts)[11] .The samples were stored in distilled water (37 $\pm$ 1 ºC) in an incubator (Memmert GmbH + Co KG, Germany) for 7 days. Shear Bond Strength Test SBS: The bond strength between acrylic tooth and PMMA base was measured in shear mode by using compression machine (Unconfined Compression Machine, Soil Inc., Model CN 472, EVANSTON, Ill. U.S.A). The bond strength (B) in MPa was calculated based on the load (F) in (N) at fracture and adhesive surface area (S) in mm^2.

$$S = \frac{\pi}{4} \text{ x } D^2$$

where π= 22/7

D (diameter) = 5 mm, S = 19.64 mm^2

B (MPa) = F/S (Buyukyilmaz and Ruyter, Vergani *et al.*)[12,13]

RESULTS AND DISCUSSION

The results of this study (Tables 1, 2, and 3) showed that SBS of acrylic teeth to microwave cured denture base resin using new prepared FRP (MINARA) Flask is significantly higher than that of acrylic teeth to water bath cured denture base resin using Metal Ash Flask. These results are supported by many authors which reported that the bond strength of acrylic teeth to denture base resin is due to the diffusion and polymerization of monomer across the tooth base interface to form interpenetrating polymer networks. The efficiency of the attainment of such a bond depends primarily on the rate at which monomer diffuses from the base resin mixture. Higher diffusion rates of the monomer of the denture base polymer mixture into the acrylic resin polymer teeth is achieved with increasing polymerization temperature [12]**.** The results of this study reveal that chemical bonding have taken place in both, microwave, and water bath techniques. However, the rate of monomer diffusion could be higher in microwave technique that provide higher bond strength of acrylic teeth (19.38 $\pm$ 1.61 MPa) when compared to that of water bath technique (17.61 $\pm$ 1.46 MPa). This bond strength probably is based on the pe,netration depth of the monomer. Polyzois and Dahl,[16] and Abood[17] used peel test according to the ISO. 3336–1977, and curing cycle 3 minutes at 500 watts. They reported that the size of the tested specimens (more than 3 mm thickness) used in their study implies the formation of porosities which was a likely explanation for the bond failure after microwave curing.

Table(1): Mean and standard deviation of SBS for acrylic teeth types cured by water bath using Metal Ash Flask, and microwave technique using FRP flask.

water bath technique (Ash) Flask				
Type of crylic Teeth	**Metal Ash Flask untreated**		**Metal Ash Flask treated**	
	Mean (MPa) ± SD	**N**	**Mean (MPa) ± SD**	**N**
Abdul–Nour	17.08 ±0.26	8	19.52 ±0.29	8
Super–Cryl	17.00 ±0.23	8	19.53 ±0.21	8
Flori–Dent	15.63 ±0.23	8	17.22 ±0.27	8
Major–Dent	15.70 ±0.27	8	17.39 ±0.21	8
Super–Lux	17.30 ±0.20	8	19.75 ±0.27	8
Microwave technique (MINARA) **Flask.**				
	New FRP Flask untreated		**New FRP Flask treated**	
Abdul–Nour	18.51± 0.19	8	21.33± 0.17	8
Super–Cryl	18.43± 0.27	8	21.25± 0.20	8
Flori–Dent	17.05± 0.22	8	19.13± 0.50	8
Major–Dent	17.50± 0.13	8	19.56± 0.21	8
Super–Lux	19.04± 0.25	8	22.01± 0.21	8

Table (2): Analysis of variance (ANOVA) for levels of curing technique, surface treatment, type of acrylic teeth and their interactions.

Source of Variance	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	***p*-value**
Curing Technique	1	125.14	125.14	2010.7	0.0001*
Surface Treatment	1	219.72	219.72	3530.5	0.0001*
Type of Acrylic Teeth	4	134.33	33.58	539.58	0.0001*
Curing Technique × Surface Treatment	1	1.68	1.68	27.01	0.0001*
Curing Technique × Type of Acrylic Teeth	4	1.37	0.34	5.50	0.0004*
Surface Treatment × Type of Acrylic Teeth	4	6.47	1.62	26.00	0.0001*
Curing Technique × Surface Treatment × Type of Acrylic Teeth	4	0.07	0.02	0.30	0.8784
Error	140	8.71	0.06		
Corrected Total	159	497.50			

* Highly significant DF = Degree of freedom

Table (3): Duncan's multiple range test for the interaction between types of acrylic teeth and curing technique using Metal Ash Flask, and New FRP flask.

Curing technique	Type of Acrylic Teeth (Means in MPa)				
	Abdul–Nour	**Super–Cryl**	**Flori–Dent**	**Major–Dent**	**Super–Lux**
Water Bath	18.30 ± 0.32 D	18.26 ±0.33 D	16.42 ± 0.21 F	16.54 ± 0.23 F	18.52 ± 0.32 C
Microwave	19.92 ± 0.37 B	19.84 ± 0.37 B	18.09 ± 0.28 E	18.53 ± 0.27 C	20.52 ± 0.39 A

Means with different letters horizontally and vertically are statistically significant.

In this study, thickness of denture base resin was 2.5 mm (ADA, 1975), lower wattage (80 watts) and longer curing cycle (15 minutes per side, followed by 1 ½ minutes at 500 watts) was used for microwave curing method. This curing cycle enhanced the exothermal heat to be dissipated quickly to the surrounding investing material, and the low wattage that was selected for the curing facilitates spreading of heat in a gradual manner so that boiling point of the monomer which is 100.3 ºC is not reached. So, in this study the samples that cured by microwave technique were free of porosities, and this give another explanation for higher SBS of acrylic teeth to microwave cured resin, this study agree with results of Al-Omari[18].

CONCLUSIONS

The present study a metal mold has been designed and prepared to be used for production of FRP (MINARA) flask from glass fiber re–inforced plastic with the same dimensions, form and divergence of metal Ash flask. Bond strength of acrylic teeth was significantly higher in microwave FRP(MINARA) flask in relation to water bath technique (Metal Ash flask).

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